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# A SYSTEMS ANALYSIS TO DEFINE THE TYPES OF RATIONS NEEDED TO SUPPORT AMPHIBIOUS OPERATIONS


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**FINAL REPORT 1980 TO 1984**





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**ADVANCED SYSTEMS CONCEPTS DIRECTORATE**

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Principal project requirements centered on developing the minimum ration system needed to support amphibious operations in the 1990-2000 time frame. The approach called for: (1) identifying the future combat mission requirements of the Marine Corps; (2) developing preferred ration design objectives that best supported these mission requirements; and (3) subsequently designing a ration system concept that optimized these preferred objectives. Specific areas covered in the analysis included identification of the (future) combat role of the Corps, specific geographic scenarios, climate extremes, mission duration, force size, mobility requirements, logistics support, etc. From these evaluations a set of specific ration design requirements were formulated. Principal requirements identified included: (1) the need for an individual operational ration system suitable for use in all climates; (2) the need for a low-volume ration to provide extended mission endurance; and (3) the need for meals that are open-and-eat in nature and require no carried drinking water for their preparation. Efforts were then focused on translating the ration design requirements into a responsive (hypothetical) prototype ration system (continued on back)

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As a result of this analysis, a preferred concept for the amphibious ration was developed. The ration would consist of between four to six 900-Kcal intermediate moisture modules. This configuration would offer the optimal calorie fit under existing climate requirements. The components would consist of two 450-Kcal bars, one entree and one fruit to be eaten as is (no preparation required).

This concept reflects a ration system that is both flexible and responsive to the varied requirements of amphibious assault operations and provides the combat Marine with a practical and convenient form of subsistence.

# EXECUTIVE SUMMARY


## Objective

The objective of this project was to develop alternative subsistence concepts in support of USMC amphibious combat operations in the 1990s to 2000 time frame.

## Requirements

Principal project requirements centered on developing the minimum system of rations, packets, and/or supplements needed to support amphibious operations in the future. The proposed system is to provide the Marine Air-Ground Task Force (MAGTF) Commander optimal flexibility in addressing subsistence requirements for the broad range of scenarios involving amphibious assault combat operations.

## Technical Approach

The overall technical approach called for: 1) identification of the Corps' future combat mission requirements; 2) development of preferred ration design objectives that best support these mission requirements; and 3) subsequent proposal of a ration system concept that optimizes these preferred design objectives.

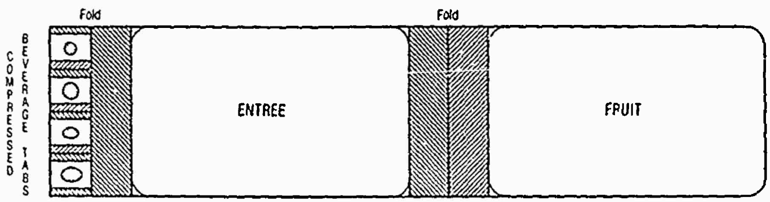
Relevant topics addressed in this report include combat mission roles, specific geographic scenarios, climatic extremes, mission duration, force size, mobility requirements, and logistics support. Ration design objectives included as desirable: 1) an individual operational ration system for use in all climates; 2) a low-volume, low-weight ration that would reduce the Marines' carried load or extend mission endurance; and 3) meals that were open-and-eat in nature and not dependent on canteen water for their preparation. Analysis also indicated that substantial variety in menus was not positive assurance of consumption and, as such, variety could be more limited in this ration system in an effort to reduce manufacturing costs.

Efforts were then focused on applying these ration design objectives to a prototype ration system.

## Results

As a result of these investigations, project participants developed a preferred concept for an amphibious combat ration. The concept's basic food form is an intermediate moisture product that provides the individual Marine with an easy-to-eat item requiring no preparation or canteen water to reconstitute. The product is bar shaped to facilitate eat-on-the-move conditions and manufactured so that free water is bound to protein, fat, or carbohydrates to offer some level of protection from freezing solid in below-freezing temperatures. This particular product design would additionally enhance shelf stability. The total system consists of up to six 900-Kcal menus. This configuration offers the optimal calorie fit under current climate requirements.

The proposed components of each menu would consist of two food bars, one entree, and one fruit. The food items are to be eaten as is, or optionally heated through a chemical (exothermic) reaction. Packaging is of a plastic/foil laminate design to offer protection against CB contamination. An attached accessory packet contains compressed beverage tabs (one hot drink and one cold drink), artificial sweetener and compressed cream. These would be sealed in an extended end-flap on the ration. Improved alternative materials are to be investigated to replace toilet tissue currently used. In any event, the tissue supply is to be packaged to the length and width dimensions of the food components to minimize its profile.




The end result reflects a ration system that is optionally suited to the varied requirements of amphibious assault operations and provides the combat Marine with a practical, convenient form of subsistence.

# PREFACE

The objective of this Marine Corps project was to define the required types of rations needed to support amphibious operations in the 1990's. This Military Service Requirement (M79-4) was assigned to the Directorate for Systems Analysis and Concept Development, the US Army Natick Research and Development Center and was completed during 1980 to 1984.

The proponent of this effort was the Food Service Section, Directorate of Facility and Services Division, Headquarters, US Marine Corps, Washington, DC.

This report has been prepared to document the identification and evaluation of the future amphibious combat role of the Marine Corps, its impact on end-user subsistence requirements in the field, the development of alternative ration concepts, and the selection of a preferred system.

The nature of such a project dictates that a multidisciplinary approach be adopted to address successfully and integrate all of the various aspects of this system. The contributions over the last 4 years from many knowledgeable individuals make for a difficult task in crediting each one. As such, the authors wish to express appreciation to all those individuals whose contributions may not be specifically acknowledged in this text.

The following six organizations and their individuals have provided support worthy of specific recognition.

1. Food Service Section - Facilities and Services Division, Headquarters, US Marine Corps

Under the foresighted leadership of this organization, the need to investigate the future (long-term) requirement for amphibious rations was recognized and supported. LTC Larry Edwards was instrumental in providing positive input throughout the investigation.

2. US Marine Corps Joint Technical Staff Representative, NRDEC

This project has transitioned from Major William Kastner to Major Thomas Parker and presently to Major Richard Cassidy. The collective efforts of these officers have been of great assistance in coordinating requirements between NRDEC and various Marine Corps elements.

3. Food Engineering Laboratory (FEL), NRDEC

In support of this project Ms. Vera C. Mason Ms. Alice L. Meyer and Ms. Mary V. Klicka, Chief Ration Design Evaluation Branch, were responsible for researching, documenting, and writing Natick Technical Report 82/013, A Summary of Operational Rations.[1]

Ms. Virginia White and Ms. Leslie Wyzga also of the Ration Design Evaluation Branch are credited with the development of carbohydrate-enhanced A and B Ration menu concepts.

4. Science and Advanced Technology Laboratory (SATL), NRDEC

Dr. Barbara Edelman-Lewis, from the Behavioral Sciences Division, was responsible for an interim report on Human Factors Considerations for Rations in Different Climates.

Mr. Jerry Jarboe, Physical Sciences Division, is credited with detailed analytic evaluation of the existing rations systems.

5. Individual Protection Laboratory (IPL), NRDEC

Ms. Rosemary Lamba of the Clothing Division was instrumental in providing data on the various combat clothing systems.

6. Directorate for Systems Analysis and Concept Development (DSACD), NRDEC

Initial guidance for support of this project was provided by Dr. Robert Byrne (former Chief) and Mr. Richard Richardson (former Program Manager). Subsequent project assistance was provided by Mr. Mark Davis (Program Manager). Mr. Philip Brandler (Director) and Mr. Robert J. Walsh (Program Manager) have seen this project through successful completion. Secretarial support was provided by Mrs. Diane Sears and Ms. Katrina Schuh, and programming assistance was provided by Mrs. Kathy-Lynn Evangelos.

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# A SYSTEMS ANALYSIS TO DEFINE THE TYPES OF RATIONS NEEDED TO SUPPORT AMPHIBIOUS OPERATIONS

## I. INTRODUCTION

### Objective

The broadbase objective of this project was to define the required types of rations needed to support Marine Corps Amphibious Assault Operations, including identification of the minimum rations, packets, and/or supplements required to meet the projected range of missions and operational situations in the long-term (1990-2000 time frame).* Additionally, the study was to define the interface between other field food service systems to provide flexibility to the Marine Air/Ground Task Force (MAGTF) Commander in the selection of the meal discipline that would best suit the particular need.

### Approach

The overall technical approach sought to: 1) identify, in broadbase terms, the combat mission requirements of the Corps; 2) develop from these requirements ration design objectives that support the mission; and 3) propose subsequently a ration system concept that optimizes the design objectives.

Initial phases of the analysis included identification of the Corps projected combat mission including specific geographic scenarios, climate extremes, mission duration, force size, mobility requirements, logistics support, etc. From these evaluations a list of preferred ration design objectives was then formulated. The project was then presented to representatives of the Marine Corps Food Service Office in Washington DC for concurrence on the validity of the amphibious combat mission model and on the importance and desirability of the proposed ration design objectives. The presentation was well received and those in attendance agreed to continue the project on its planned course.

Efforts at Natick RD&E Center then focused on applying the proposed design objectives to the concept development of an amphibious combat ration.

### Design Parameters

To help insure that the proposed end product paralleled Marine Corps expectations, the following parameters were established between NRDEC and the Marine Corps Joint Technical Staff Representative.

The first of these addressed the issue of designing a ration system for use in peacetime or wartime. Preliminary data indicated that the relative importance of an individual combat ration under combat conditions becomes greatly diminished based on the fast moving pace of an amphibious assault, the limited

*Revised Technical Plan - revision #2, A Systems Analysis to Define the Required Types of Rations Needed to Support Amphibious Operations (M79-4), 4 May 1982.

duration of such a mission, and the psychological effects that would likely be manifested. Conversely, during other than wartime conditions (i.e., training exercises, functioning as a peacekeeping force, etc.) it is reasonable to expect that there would be a reordering of the Marines' individual priorities focusing more on an increased awareness of food. As a result, and with Marine Corps concurrence, NRDEC set out to design an amphibious assault ration for use in combat that in peacetime could fall short of meeting end-user expectations.

The second design parameter, along somewhat similar lines, sought concurrence on simplifying the ration's design to the maximum extent possible. It followed that if the ration were designed for combat conditions, researchers could and should take advantage of any diminished need in the variety of subsistence during actual combat conditions. As such, efforts went into designing a ration system that, while austere in nature, would nevertheless satisfy the Marine's basic needs.

Summar

Throughout the project, the overriding philosophy has been to develop a ration system that best meets the needs of the combat Marine; as such, operational requirements have dictated the overall concept design. To support this design, new or improved technologies will, in a number of cases, be required to produce the ration at some future point. In other words, availability or the lack thereof of proven technologies was not a determining factor in the concept development. There is, therefore, some degree of risk present as to success in the development of some of these technologies. If successful, however, the result will be a ration system that optimally meets the individual Marine's combat subsistence needs.

## II. THE AMPHIBIOUS COMBAT MISSION

This section provides a broadbase overview of the Marine Corps projected amphibious combat mission followed by more detailed discussions of mission-related factors affecting ration design. The overview includes both organization structure and force tactics. Related factors that would play a prominant role in formulating the design concept were then identified for further investigation.

### Overview - Amphibious Combat Missions

The purpose of this overview is to provide needed insight into the Marine Corps' general organizational structure and, in particular, that of the Marine Air/Ground Task Force (MAGTF). For Natick R&D&E Center researchers to identify the functional criteria that would serve as the basis for the ration's overall design, a better understanding of the organizations and their mission objectives was needed.

In the early stages of the evaluation, a frequently raised issue was "Since the Marine Corps is so similar to the Army, why doesn't it just use what the Army uses?" While similarities indeed exist, the Marine Corps' standing mission, in concert with the Navy's Second, Third, Sixth and Seventh Fleets, is to maintain United States freedom of the world's sea-lanes. It is this mobility factor that makes the Corps the prime candidate for short-notice deployment to virtually any ocean-bounded region and impacts significantly on the design of any ration system seeking to optimize support for global missions. The Army relies on stationing large numbers of troops in a particular geographic region where they are most likely to be utilized (e.g., Germany) and to redeploy such forces only in the event that a potentially protracted campaign is anticipated. It is also worth noting that stationary (land-based) forces are in a better position to take advantage of group feeding alternatives and, most importantly, generally have at their disposal considerable storage capabilities.

Amphibious assaults are organized under the "Task Force" concept. This concept essentially refers to the configuration of a force to meet the specific requirements of an impending mission. Once the mission is completed the Task Force is disbanded. There are three basic levels of the Marine Air/Ground Task Force. The first level, with approximately 2,700 Navy and Marine Corps personnel, is a Marine Amphibious Unit (MAU); the second, with approximately 15,700 combined personnel, is a Marine Amphibious Brigade (MAB); and the third, with approximately 52,000 personnel, is a Marine Amphibious Force. Each of these MAGTFs are composed of four major elements: a Command Element, a Ground Combat Element, an Aviation Combat Element, and a Combat Service Support Element.

In terms of tactics, the modern amphibious assault employs a concept that is generally referred to as "Maneuver Warfare". In traditional "line of scrimmage" tactics, the opposing forces engage each other along a battle line measuring success through "terrain acquisition" as the opposing army is forced to retreat. The modus operandi of Maneuver Warfare, on the other hand, is one of "strike, disburse, then reconcentrate for the next strike". A major objective is to make the enemy certain of repeated attack, but uncertain as to <u>when</u> and <u>where</u> it will happen. The enemy must prepare for all eventualities by widely disbursing the defenses it would normally consolidate at particularly valued pieces of ground. Thus, individual enemy units become increasingly vulnerable. Timeliness and mobility are key factors - protracted engagements are not the goal of Maneuver Warfare.

In terms of mission support, both the Maneuver Warfare concept and the Amphibious Assault ("launched from the sea") concept are tangent to the more conventional concept of an established logistics "train", in the sense of a continuous supply line extending to the front. In the case of an amphibious assault, all support is ultimately dependent on the number of ships in the Task Force and their cargo capabilities. For the Marines once ashore, resupply must take the form of a rendezvous between combatant units and the support element. The less frequent the number of resupply rendezvous, the less likely the enemy will discover a unit's whereabouts, thus supporting the operational philosophy of Maneuver Warfare.

Recapping the major points of the amphibious assault mission, it is: 1) Navy Fleet integrated; 2) highly mobile; 3) not likely to engage in protracted combat situations; 4) logistically lean-and-mean; and 5) global in mission responsibility.

## Operational Design Considerations

Because of their potential impact on the final concept design, the following 10 issues were identified for further evaluation. The majority of these issues address operational situations/conditions that would have an effect on the combat Marine. Two principal objectives in the evaluations were to 1) optimally design the ration system for use under the least favorable of field conditions--not making generalized assumptions that such variables as water, fuel, time, etc., would always be available, and 2) design from the perspective needs of the individual combat Marine.

Figure 1 illustrates the 10 topics that were evaluated. Each, in turn, will be outlined and briefly discussed.

- COMBAT CONDITIONS
  - 1990-2000 Time Frame
  - All Male Force
  - Ration Indoctrination (Combat)
  - Ration Testing (Peacetime)

As previously mentioned, the ration system would be developed for use under combat conditions - specifically, combat in the 1990-2000 time frame consisting of an all-male combat force. Recent guidance from Marine Corps Headquarters outlining the role of women in the Corps (present and future) indicated no shift in the position that women would not go into direct combat situations. The effect of this position was to direct NRDEC efforts towards designing for an all-male combat force versus developing a ration system(s) that would be responsive to two different nutritional standards.

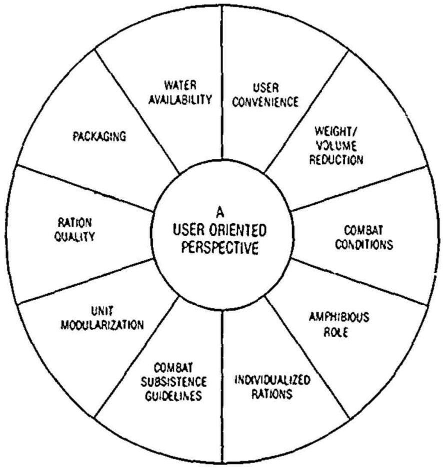


Figure 1. Operational design considerations.

In the process of developing this ration system, concern surfaced for how the ration would actually be used in the field. An investigation into how the Marine Corps specifically indoctrinates personnel in the various types of operational rations available, under what conditions they are designed to be used, how rations are to be prepared, and why is it important to use them properly turned up disappointing results. It appeared that there were no formalized training programs (at any level) specifically pertaining to ration use in the field. Of particular concern are: 1) the potential consequences for logistics foul-ups, such as ordering the wrong rations for a specific mission (as when the British Royal Marines used the British Arctic Ration in the Falkland Islands); 2) field commanders not fully appreciating the synergistic effect between personnel, adequate subsistence, performance in the field, morale, and overall mission objectives; and 3) the end user's lack of understanding the relationship between nutrition and maximized performance.

The issue of realistically evaluating, under peacetime conditions, the performance of a ration designed for use in combat will, undoubtedly remain a problem. Judicious identification of amphibious exercises that most closely resemble the "real thing" is all that can be expected in evaluating the functionality of this ration system.

- AMPHIBIOUS COMBAT ROLE
  - Navy Integrated
  - Air/Sea Incursion
  - Geographic Versatility

    Temperate/Wet-Cold/Desert/Tropical Climates

In MARCORPS 2000, the Marine Corps long-range planning document, the Corps' primary role as a quick reaction, Navy-integrated "launched from the sea' assault force was reaffirmed.[2] The implications of this role were that elements of the Corps could be quickly deployed to a variety of locations throughout the world. The ration concept would, therefore, have to be sensitive to both the differing caloric requirements and the physical problems associated with climate extremes. In addition, the logistics impact of rations on the Navy forces supporting an assault have to be considered, i.e. volume minimization.

- COMBAT SUBSISTENCE GUIDELINES
  - 90-Day Planned Duration
  - 30-Day Initial Provisioning

Whatever the force size used, it is important to determine for how long the force could potentially be involved in combat and at what point in time would various alternative ration systems be employed. Figure 2, (excerpt from the Marine Corps War Reserve Manual[3]) provides a breakdown as to the types of rations that might be utilized in the various phases of a 90-day amphibious assault mission. It is unfortunate that no other data could be found to corroborate this matrix. Note that these concepts, figures, and time frames, etc., represent planning guidelines. They are not intended to limit or restrict the possibility that other options or situations are available or could occur.

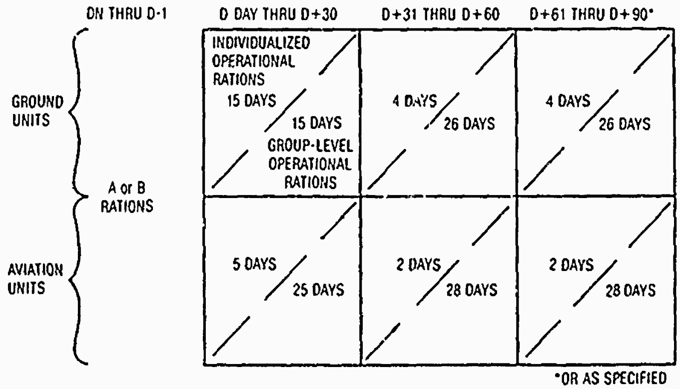


Figure 2. Subsistence time frames: 90-day incursion (War Reserve Policy Manual).

Assuming that the Marine Corps does not want to support combat personnel on individual operational rations for extended periods of time (from both a cost and morale viewpoint), and that every effort would be made to provide at least one hot meal a day as soon as possible, then the 15 days or less exclusive use of individual operational rations presented in the matrix appears to be a reasonable guideline. At the first opportunity for hot meals the preferred option would most likely consist of Tray Packs or meals of some similar technology. A more detailed analysis of Marine Corps group feeding alternatives can be found in the Natick Technical Report, Field Feeding System To Support USMC Forces in the 1990s.[4]

- INDIVIDUALIZED RATIONS
  - Infantry Configured
  - Non-Infantry
  - Vehicle-Married Crews

In assessing: 1) the typical breakdown of the various elements that compose all MAGTFs; and 2) the air/sea incursion tactics employed in an assault operation, it appeared that in order to satisfy the widest range of subsistence situations the ration system should be based on the needs of the individual Marine operating an independent combat element. In investigating the various items of troop carrying equipment (i.e., AMTRACs, CH-53Es, CH-46s, and the new LCACs and LAVs), it appeared that infantry Marines would not be married, as such, to any particular transport device long enough to give serious consideration to group rations. From a historical perspective, the old Ration, Small Detachment, 5 Person; and Meal, Landing Force, 25 Persons; and the newer Meal, Uncooked, 25-Man; and the Meal, Quick-Serve, 6-Man were available for group level feeding and were either not used, or never procured.

- WEIGHT AND VOLUME REDUCTION
  - Volume More Critical
  - Economies of Scale

While investigating the relative importance of both weight and volume as they impact on the end-user, reseachers became aware that within the limitations of the individual Marine, volume was the more critical factor. In terms of reducing the Marine's carried load or extending mission endurance using today's family of rations, a combat Marine would be far more restricted in the volume of food he could carry than in the weight of the food. In the case of future ration design, it is possible at some point that, as a result of significant volume reduction, the reverse situation could occur and weight would become the limiting factor. An example of these weight/volume differences can be seen in Table 1, which lists selective ration components, by both kilocalories per gram (Kcal/g) and kilocalories per cubic centimeter (Kcal/cc). As can be seen, caloric density in terms of Kcal/g is not always a good indicator of volume efficiency, i.e., Kcal/cc. In the first 10 items listed (rank order) in terms of volume efficiency (Kcal/cc), only 2 are seen to repeat in the left column where the components are rank ordered by Kcal/g. Admittedly, this ordering only addresses the basic composition of the food items without regard to nutritional adequacy.

TABLE 1. Weight/Volume Comparisons of Ration Components.

| Ration Component | Calories/ Net Wt (g) | Ration Component | Calories/ Net Vol(cc) |
|---|---|---|---|
| Peanut Butter | 6.4 | Coconut Candy Bar | 7.9 |
| Beef Patty | 5.9 | Orange Beverage Bar | 7.6 |
| Pork Patty | 5.9 | Peanut Butter | 7.1 |
| Beef Hash-A | 5.4 | Chocolate Pudding | 7.1 |
| Beef Hash-L | 5.4 | Caramels-A | 6.4 |
| Brownie | 5.4 | Chocolate Candy-M | 6.4 |
| Chocolate Candy-L | 5.3 | Chocolate Candy-L | 6.4 |
| Chocolate Cookie | 5.3 | Granola-L | 6.1 |
| Beef w/Rice | 5.2 | Chocolate Fudge Candy Bar-L | 6.0 |
| Chicken ala King-A | 5.2 | Sweet Chocolate Candy Bar | 6.0 |
| Spaghetti-L | 5.1 | Brownie | 5.8 |
| Chocolate Candy-M | 5.1 | Vanilla Fudge Candy Bar | 5.8 |
| Chicken w/Rice-A | 5.0 | Caramels-M | 5.7 |
| Chili | 5.0 | Lemon Bar | 5.6 |
| Beef Stew-L | 4.9 | Orange Bar | 5.3 |
| Spaghetti-A | 4.9 | Chocolate Fudge Candy Bar-A | 5.2 |
| Chicken w/Rice-L | 4.9 | Oatmeal Bar | 5.1 |
| Potato Patty | 4.8 | Pepperoni | 5.0 |
| Pepperoni | 4.7 | Chocolate Cookie | 4.9 |
| Escalloped Potatoes w/Pork-A | 4.7 | Granola-A | 4.6 |
| Escalloped Potatoes w/Pork-L | 4.7 | Chocolate Nut Cake | 4.6 |
| Sweet Chocolate Candy Bar | 4.7 | Maple Nut Cake | 4.5 |
| Oatmeal Bar | 4.6 | Pineapple Nut Cake | 4.5 |
| Chocolate Nut Cake | 4.6 | Orange Nut Cake | 4.3 |
| Granola-A | 4.6 | Beef Patty | 4.3 |
| Orange Bar | 4.6 | Cherry Nut Cake | 4.2 |
| Lemon Bar | 4.6 | Cheese Spread | 4.1 |
| Beef Stew-A | 4.6 | Beef Hash-A | 4.0 |
| Maple Nut Cake | 4.6 | Vanilla Pudding | 4.0 |
| Cocoa-M | 4.6 | Fruitcake | 3.9 |
| Granola-L | 4.6 | Chicken ala King-A | 3.9 |
| Vanilla Pudding | 4.5 | Fig Bar | 3.9 |
| Chocolate Pudding | 4.5 | Pork Patty | 3.8 |
| Vanilla Fudge Candy Bar | 4.5 | Chicken w/Rice-A | 3.7 |
| Chocolate Fudge Candy Bar-L | 4.5 | Beef Hash-L | 3.6 |
| Coconut Candy Bar | 4.5 | Spaghetti-A | 3.6 |
| Chicken Stew-A | 4.4 | Apple Jelly | 3.6 |
| Crackers | 4.4 | Beef Jerky | 3.5 |
| Chicken Stew-L | 4.3 | Sugar | 3.5 |
| Caramels-M | 4.3 | Chewing Gum | 3.5 |
| Pineapple Nut Cake | 4.3 | Beef Stew-L | 3.4 |
| Orange Nut Cake | 4.2 | Escalloped Potatoes w/Pork/A | 3.4 |
| Cherry Nut Cake | 4.1 | Beef Stew-A | 3.4 |
| Cheese Spread | 4.0 | Chili | 3.3 |
| Caramels-A | 4.0 | Chicken Stew-A | 3.3 |
| Fruitcake | 4.0 | Apple Jelly | 3.1 |
| Cream Substitute | 4.0 | Escalloped Potatoes w/Pork-L | 3.1 |
| Sugar | 4.0 | Spaghetti-L | 2.9 |
| Orange Beverage Bar | 4.0 | Hot Dog | 2.9 |
| Mixed Fruit | 3.9 | Catsup | 2.7 |
| Chocolate Fudge Candy Bar-A | 3.9 | Cocoa-M | 2.7 |
| Strawberries | 3.9 | Beef w/Rice | 2.5 |

M=MRE A=AP L=LRP

- UNIT MODULARIZATION

  - Concept Alternatives

    Universal Ration

    Core Ration With Specific Climate Supplement

    Climate Designated Ration

  - Optimal Flexibility

  - Simplified Logistics

Three design options were identified and presented to the Marine Corps Food Service Officer for consideration. Option one represented a universal ration concept that would have the desired characteristics and flexibility required for use under virtually all amphibious scenarios. The second option would offer a core ration for use under all conditions accompanied by a set of supplements designed for use in specific climates (i.e., temperate, cold, hot). The supplements would then be added to the core ration for use under the appropriate operational conditions. The third option would provide up to three different rations for specific use in either temperate, hot, or cold climates. The Food Service Office, upon reviewing the three alternatives, fully supported the concept of developing a universal ration.

From a logistics perspective, the universal ration concept is the most appealing in that one ration would satisfy all amphibious situations. There would be little potential for error in shipping the wrong ration or supplement to a specific geographic area. It is likely, too, that a single ration concept would prove more economical in volume (to both the Navy and the individual Marine) and in cost.

- RATION QUALITY

  - High Acceptance

  - Maximized Quality

  - Minimize Menu Cycle

As one of four traditional ration design requirements[1], customer acceptance is considered essential for ensuring continued consumption of any ration. Typically, a variety of meals has prevailed in ration design as a driving consideration for ensuring continued customer acceptance. The question now is how many meals should be developed for the new system? In attempting to determine this, it is important to know how both the quality and the variety of the meals provided will affect the level of customer acceptance over (x) period of time given (y) number of meals. Is there a correlation between these two factors, and if so to what degree? As this cannot currently be determined, it would appear that until this type of data becomes available, the question of how many different menus should be produced in a ration system to maintain a desirable level of customer acceptance over a 15-day period becomes an arbitrary decision at best.

- PACKAGING

  - Configuration

  - Storage

  - Chemical/Biological Protection

While it is taken for granted that the ration packaging must be strong and protective, concern nonetheless exists that the weight and volume of the packaging be limited or reduced in an amphibious ration. Product configuration to improve both ration storage and accessibility at the level of the individual Marine is emphasized. Pallet configurations to reduce the logistics burden on both the Marine Corps and the Navy were additionally investigated.

As the Corps anticipates the possibility of conducting assaults in chemically/biologically (CB) contaminated environments, as stated by the Food Service Office, the need arises for some level of protective packaging in this regard. It is felt that the requirement for CB protective packaging should not be at the individual meal level but rather at the case level. While such protection is not a part of this study, it is felt that a detailed analysis would bear out the fact that case level protection would provide the better cost/benefit alternative.

- WATER

  - No Requirement For Food Preparation

  - Beverages Only

  - Climate Extremes

Based on a number of negative Marine Corps Key Experiences Evaluation System (MCKEES) reports,* it was felt that the most suitable ration design would be one that did not freeze in cold weather or require water to rehydrate food components. In instances where less than optimal quantities of drinking water are available to the fielded Marine, a dehydrated ration could further exacerbate the situation. While neither of these situations could be considered "life threatening" to the combat Marine, every attempt was nonetheless made to design a ration that would not lend itself to further problems.

- USER CONVENIENCE

  - Eat-On-The-Move Capability

  - Fully Prepared Items

  - No Ancillary Equipment

*See Chapter III, Field Ration Evaluations.

To the combat Marine, perhaps the most important characteristic of a ration system, besides taste, is how convenient the ration is to use. As previously stated, one of the most important objectives in the development of this ration concept was a wide-range adaptability to varying mission conditions in combat. The optimal ration therefore for the early dynamic stages of an amphibious assault is one that can conveniently be eaten while on-the-move, is made up of a limited number of open-and-eat components, and requires no additional equipment to prepare or heat.

## Summary

Briefly recapping, the overall ration concept needed to be compatible with amphibious assault operations under combat conditions in which a wide range of variable operational situations could occur. Project participants determined design considerations most universally desirable. These included an individual, volume efficient, modularized ration for exclusive use of periods up to 15 days in all climates. Convenience of use is strongly emphasized in the limited number of components offered, the packaging system, and the preparation-free (open-and-eat) style components.

## III. CONCEPT DESIGN ANALYSIS

In the process of developing the preferred ration design concept, project members conducted evaluations that included an analysis of previous Marine Corps field ration experiences and tests, an overview of several design considerations from a nutritional perspective, several analytic evaluations pertaining to ration modularization, weight, and volume, and lastly an analysis of alternative design concepts. These evaluations, coupled with the operational design considerations from Section II, formed the overall framework for what would be the preferred ration design concept.

### Field Ration Evaluations

After Action Reports - In assessing the ration design from a human factors perspective, it was felt that useful information might be gained from an evaluation of previous Marine Corps and NRDC experiences in the field. While specific references pertaining to the use of individual operational rations in the field were limited, a number of relevant points were, nonetheless, identified. The following sources provided the major portion of data in this regard: 1) the Marine Corps Key Experiences Evaluation System (MCKEES) data base;[5] 2) an NRDEC survey of Marine Corps combat veterans;[6] 3) a Norway "Cold Winter" exercise evaluation; and 4) relevant NRDEC laboratory/field survey evaluations.

Having learned of the MCKEES data base, Natick researchers requested from the Marine Corps Development and Education Command (MCDEC) a printout of all exercises with applicable references to field ration experiences, climate induced problems, logistics support, and medical incidences. To provide a better understanding of the nature and purpose of MCKEES, a brief excerpt from the "Background" section of that report is offered.

> Through the many training exercises conducted each year, the Marine Corps gains a wealth of information, experience and new knowledge. The critical issue here is to insure that we retain this experience, knowledge and use it in the most effective manner in the future. Since training exercise reports are numerous and often lengthy, an effective search to identify innovative tactics and techniques, or trends in problems, is a difficult task. Exercise reports are often treated in isolation with the result that innovative tactics or trends may go unrecognized. As a result of these problems, it became evident that screening and evaluating of training exercise reports might be more effectively accomplished through the use of automated data assistance. Therefore, development of the Marine Corps Key Experiences Evaluation System (MCKEES) was initiated. MCKEES is an automated retrieval system which allows rapid access to training experiences thereby facilitating centralized analysis. Furthermore, by highlighting problem areas, MCKEES can allow Commanders to orient training in a direction to benefit previous lessons learned and to prevent the reoccurrence of earlier mistakes.

The following exercises were excerpted from either the MCKEES data base or from various Marine Corps After Action Reports:

- Brave Shield
- Bead Chevron
- Palm Tree
- Alloy Express (82)
- Cold Winter (79)
- Cold Winter (81)
- Coldex (81)

Several similar observations in the reports of the above exercises cite the difficulty in thawing frozen rations, specifically, the Meal Combat Individual (USA) and British Assault Ration (BAR). Individuals, in some cases, suffered severe abdominal cramps attempting to eat frozen ration components. Attempts at heating rations met with varying degrees of frustration - in the case of MCIs, scalding was a constant hazard. While the Meal, Ready-to-Eat, Individual (MRE) was not available for testing during Alloy Express (82), the evaluators knew of this developmental item and voiced concern over the potential for components freezing during cold weather exercises.

In cases where rations required considerable preparation, as with the BAR, individuals were reluctant to prepare the main meal when a definite "mountup" time was unknown. As a result, many main meal packets went uneaten or discarded. Snacks were consumed in place of the meal, resulting in inadequate caloric intakes.

In the case of the Marine Corps Assault Packet positive input was noted relative to the pocket-size dimensions of the ration components.

With the exception of the previous comment, it was discouraging to NRDEC to see no mention, particularly in regards to long range reconnaissance patrols, of any volume-related issues or thermal signature (ration heating) concerns. The only topics mentioned relative to these types of patrols included excessive weight and freezing problems associated with the MCI, the problem of a particularly smoky Norwegian stove, and the fact that these most conservatively equipped people (i.e., reconnaissance patrol Marines) were carrying squad stoves to cook on.

References pertaining to water availability, subsistence storage containers, ration reconstitution, and individual dehydration were found scattered throughout the literature. One such reference reads as follows; "An important side effect of eating LRPs (as well as the Assault Packet) is the almost universal feeling of thirst that follows, reminding Marines who were unaware of their dehydration that water was needed." While this "thirst alarm" is apparently regarded as a positive feature of both LRPs and Assault Packets, such an observation raises serious question as to how the Marine is suppose to deal with this thirst stimulus in the event that less than optimal quantities of drinking water are available in the field. In another field test, it was observed that Marines, again with less than optimal quantities of water, preferred to use the water to reconstitute the Assault Packet (main meal) before eating. Previous instructions to the Marines had stated that the components could be eaten dry.

During exercise Cold Winter and Coldex (81), water was not carried. Instead, snow and ice were routinely melted. In this particular case, it was fortunate that unlimited fuel was available. A recommendation was put forth in the After Action Report that in the future, Marines be provided with an unbreakable stainless steel thermos or freezeproof canteen so that water would be continuously available for hot beverage components (hot/wets) on the march. Several references pertaining to the problem of dehydration of Marines were noted in the same literature.

In numerous exercises (particularly in the cold weather) the positive morale effect of hot food could not be overstated. In one hot weather exercise, medical reports noted that the majority of medical admissions were due to reduced intakes of food and water.

Eating Habits in Combat - In 1982 a survey of U.S. Marines with combat experience was conducted by NRDEC in order to assess eating habits in combat.[6] Of 1,000 surveys mailed out, 475 completed questionnaires were returned. Table 2 summarizes selected demographic characteristics of the respondents at the time that they were engaged in combat.

TABLE 2. Demographic Characteristics of Survey Sample (N=475) at Time of Combat and Combat Situation Characteristics.[6]

| | |
|---|---|
| Age (mean) | 26 yrs |
| Rank | |
| Enlisted | 41% |
| Officers | 59% |
| Combat Location | |
| Vietnam | 72% |
| Santo Domingo | 1% |
| Korea | 11% |
| WW 2 PAC | 15% |
| Combat Duration | |
| 1-3 days | 32% |
| 4-14 days | 21% |
| 15 days or longer | 47% |

The following is a brief summary of the survey results by topic:

Amount eaten during combat. Respondents were asked how much they ate on the first 3 days of their first and second combat situations. Few respondents (less than 5%) reported eating more than usual during combat. Table 3 shows the percentage of respondents who reported eating three-quarters of the usual amount or less. The percentage declines from 68%, on the first day of the first combat situation, to 45% on the third day of the second combat situation.

TABLE 3. Respondents (%) Who Reported Eating Less Than Usual During Combat.[6]

| | DAY 1 | DAY 2 | DAY 3 |
|---|---|---|---|
| FIRST COMBAT SITUATION | 68% (N=447) | 59% (N=350) | 53% (N=286) |
| SECOND COMBAT SITUATION | 53% (N=330) | 50% (N=243) | 45% (N=213) |

Table 4 shows that the average amount reported eaten on the first day of the first combat situation was about half the usual amount. The amount increased to slightly more than three-quarters of the usual amount by the third day of the second combat situation. Although respondents were not asked about subsequent days, the averages in Table 4 indicate a leveling-off at the three-quarter amount.

TABLE 4. Average Amount Reported Eaten During Combat in Relation to Usual Amount.[6]

(0=NOTHING, 1=USUAL AMOUNT)

| | DAY 1 | DAY 2 | DAY 3 |
|---|---|---|---|
| FIRST COMBAT SITUATION | 0.58 (N=447) | 0.70 (N=350) | 0.75 (N=286) |
| SECOND COMBAT SITUATION | 0.71 (N=330) | 0.77 (N=243) | 0.78 (N=213) |

Reasons for eating more or less. Respondents who reported eating more or less than usual during combat were asked to explain why. The stated reasons were classified into categories derived from a review of the range of answers provided.

Only a small percentage of respondents ever stated eating more than usual during combat. Two reasons were reported for doing so; fear, and previous or anticipated food deprivation. The first may be an example of stress-induced overeating.[7] In the second case, respondents were either very hungry or were stocking up.

Table 5 provides a breakdown of the reasons for eating less than usual on each day of the first and second combat situations. The reasons are listed in the order of the average percent mentioned (see the last column of Table 5). Note that the percentages in a column sum to more than 100%, since respondents were free to state more than one reason for eating less.

TABLE 5. Reasons for Eating Less Than Usual During Combat Mentioned by Respondents (%).[6]

| REASON | FIRST COMBAT SITUATION Day 1 | Day 2 | Day 3 | SECOND COMBAT SITUATION Day 1 | Day 2 | Day 3 | AVERAGE |
|---|---|---|---|---|---|---|---|
| ENGAGED IN COMBAT | 59% | 53% | 58% | 71% | 71% | 66% | 63% |
| FEAR (NERVOUS, TENSE, SCARED) | 32 | 22 | 13 | 20 | 11 | 8 | 18 |
| NOT HUNGRY | 17 | 15 | 14 | 17 | 14 | 14 | 15 |
| SUPPLIES NOT AVAILABLE | 11 | 9 | 10 | 8 | 12 | 14 | 11 |
| WEATHER | 7 | 9 | 13 | 6 | 6 | 8 | 8 |
| TIRED, SICK | 3 | 4 | 10 | 3 | 6 | 8 | 6 |
| FOOD BAD | 4 | 4 | 5 | 5 | 5 | 7 | 5 |
| FOOD NOT IMPORTANT | 7 | 4 | 3 | 2 | 4 | 1 | 4 |
| FOOD INCONVENIENT INTERFERED W/ EQUIPMENT | 3 | 4 | 5 | 3 | 4 | 2 | 4 |
| RESPONDENTS (N) | 288 | 191 | 134 | 157 | 105 | 84 | - |

Table 5 shows that the most frequently mentioned reason for eating less was "engaged in combat," indicating that there is insufficient opportunity during combat to eat. Examples of responses in this category are "too busy for chow," "under constant attack", and "on patrol all day and night so there was no opportunity to eat." "Fear" is mentioned as a reason 32% of the time on the first combat situation. Sample responses are "tense," "anxiety," "more than a little scared," and "bundle of nerves." The percentage of "fear" responses declines markedly over the subsequent two days of the first combat situation and over the three days of the second situation. "Not hungry" is mentioned between 14% and 17% of the time. Next in frequency of mention were "supplies not available" ("shortage of rations," "only issued one meal"), "weather" ("temperature was higher than I was used to," "oppressive heat made appetite subside") and "tired, sick" ("diarrhea," "too exhausted to prepare food"). Respondents also mentioned that they ate less because of the quality of food ("bad," "tasteless," "contaminated"), and the inconvenience of preparing or carrying rations ("food too heavy to carry," "could not carry much food because it interfered with carrying ammunition").

Ratings of what determines how much is eaten in combat. Respondents were asked to rate the importance of several factors in determining how much they ate during combat. Table 6 shows that the two most important factors in determining how much was eaten during combat were the lack of time to prepare food and the lack of time to eat it. This result agrees with the answers to the open-ended question, in which "engaged in combat" was mentioned most often as the reason for eating less than usual. Both findings demonstrate the importance of time in determining how much is eaten in combat. Table 6 shows that other factors of importance are a lack of appetite, the weather conditions, and the quality of the food. These factors were also mentioned as reasons for reduced consumption in the earlier part of the questionnaire.

TABLE 6. Mean Rating (Seven Point Scale) of Reasons Important to the Amount Eaten During Combat, and the Respondents (%) Rating the Reasons "5" (Somewhat Important) or Above.[6]

| Reason | Rating (Mean) | Respondents (%) Rating "5" or Above | Respondents (N) |
|---|---|---|---|
| NOT ENOUGH TIME TO PREPARE FOOD | 4.97[a] | 65% | 442 |
| NOT ENOUGH TIME TO EAT FOOD | 4.96[a] | 67 | 440 |
| DID NOT FEEL HUNGRY | 4.45[a] | 52 | 436 |
| BAD WEATHER | 4.38[b] | 54 | 441 |
| BAD FOOD | 4.31[b] | 47 | 439 |
| NO FOOD AVAILABLE | 4.25[c] | 47 | 430 |
| WAS EXHAUSTED | 4.21[c] | 49 | 443 |
| TOO MUCH TROUBLE TO PREPARE FOOD | 4.10 | 47 | 440 |
| WAS SCARED | 3.93 | 39 | 441 |
| FOOD WAS COLD | 3.72 | 37 | 442 |
| DID NOT FEEL WELL | 3.40 | 26 | 438 |

[a]$p < .001$
[b]$p < .01$
[c]$p < .05$

Comments on feeding in combat. The final section of the questionnaire provided respondents with the opportunity to comment on how and what troops should be fed in combat. Respondents commented on several generally desirable aspects of operational rations. Table 7 shows the frequency of the comments when classified into seven categories.

TABLE 7. General Properties of Combat Rations Respondents (%) Mentioned as Desirable.[6]

| | Respondents (N = 412) |
|---|---|
| EASY TO PREPARE | 50% |
| EASY TO CARRY | 34% |
| TASTY | 25% |
| HOT MEALS | 22% |
| CALORIES, ENERGY | 16% |
| NUTRITIOUS | 13% |
| VARIETY IN MEALS | 12% |

Half the number of respondents mentioned that rations should be easy to prepare. Examples of comments in this category are "quick to fix," "foods that need no preparation can be eaten when time permits" and "packages that open easily." Thirty-four percent mentioned the need for rations to be easy to carry. Some of the comments in this category were "combat rations should be compact so they take up little space," "do away with cans so that the man is able to carry more food with him," "we need items that can be easily stored in pockets and are not bulky." Comments concerning taste, hot meals, and other ration characteristics were made with lesser frequency.

Comments concerning ease of preparing and carrying rations often concerned the need to simplify the packaging, to reduce the number of components, and to make the refuse easy to dispose. Frequently, respondents mentioned that combat rations should be consumable hot or cold. Several commented on the problems of heating food with equipment using open flames, thus risking detection by enemy forces. Heat tabs were frequently in short supply or did not heat food properly. Several noted that, with heavy rations, any excess food was discarded, and only the minimal amount was carried. Some expressed a desire, especially on the first day of combat, for ration components best suited for eating on the run, such as "quick energy" granola bars, beef jerky and the like; these can be eaten in stages and over a period of time, as the situation allows. Freeze-dried and compressed components were praised for their convenience and taste, but frequently the lack of sufficient water for rehydration was seen as detracting from the usefulness of these ration components. For example, one Marine wrote "I'm concerned that freeze-dried or dehydrated foods (are) not a proper substitute for canned foods - there are many days that I find the availability of water lacking - without canned fruit, my company on one occasion would have been in terrible shape."

In summary, the goal of the combat veteran survey was not to assess the adequacy of a particular ration system or concept, but to address the general question of how much troops eat during combat and what factors determine how much they eat.[7] The present results suggest that during the first day of combat, troops eat considerably less than their normal amount. While troops tend to eat more on successive days, the trend in how much they eat indicates a leveling off in the amount at a point corresponding to three-quarters of the usual amount.

The reduced level of consumption is not the result of an inadequate food supply. Although lack of supplies is mentioned as a reason for eating less by 10% of the respondents, the principal reason for eating less is the lack of time to prepare and to eat food. Respondents mentioned "engaged in combat" most frequently as a reason for eating less. On the seven-point scale ratings, "not enough time to prepare food" and "not enough time to eat food" were rated as the most important reasons in determining how much was eaten. Finally, in commenting on how and what troops should be fed in combat, the most frequent comment, made by 50% of the sample, was that rations should be easy to prepare; 34% mentioned the need for rations to be easy to carry. Clearly, the ease of preparing, eating, and carrying food were the most critical factors for this sample in determining how much is eaten during combat.

As indicated in the survey of combat veterans, convenience is an important aspect of operational rations. As such, several convenience-related issues will be briefly explored. One issue involves the use of the MRE (Meal, Ready-to-Eat) under temperature extremes in the laboratory.[8] It should be noted that the purpose of these observations is not to evaluate the MRE, but to illustrate some potential problems that an all-weather ration should avoid.

Convenience related issues (climatic chamber tests). The impact of climatic conditions on the ease of preparing and consuming a ration (the Meal, Ready-to-Eat) was observed in laboratory simulations conducted in an environmental test chamber. The climate extremes simulated were a) Arctic cold -- 0°F and 10% humidity, b) Hot, humid -- 85°F and 50% humidity (Test 1), or 95°F and 60% humidity (Test 2), and c) Hot, dry -- 85°F and 10% humidity. The active duty military personnel participating in each test were appropriately dressed.

In each test, the ration was provided at the end of an approximately 3.5 hour period during which personnel alternated 20 minutes of rest with 20 minutes of walking on a treadmill. Water was freely available throughout each test. The ration consisted of one Meal, Ready-to-Eat; some personnel received a menu with a dehydrated entree, others a menu with a wet entree. The following observations were made:

Arctic condition. Prior to conducting this test, three dehydrated beef patties were placed in a freezer (0°F) and kept there for several hours. Subsequently, one frozen patty was placed in a pan of chilled water in a 72°F room, the second patty was placed in the same 72°F room in a pan with 70°F water, while the third patty was placed in chilled water and put back in the refrigerator. In this last condition, no visible rehydration occurred. In the other conditions, rehydration occurred very slowly and in the case of the chilled water remained incomplete after 1 hour. This experiment would indicate that in Arctic conditions, effective rehydration requires the addition of warm or hot water in order for that patty to be consumed in a fully rehydrated condition.

Therefore, during the test of the Arctic conditions, both food and water were kept outside the arctic chamber, at a temperature of 68° to 70°F. The following observations were also made.

(a) In order to grasp and open the MRE outer and inner packets, personnel had to remove mittens, liners and inserts (no knives were provided). All test subjects eventually used their teeth to open the packages. Opening the packets took an average of 3 minutes. After opening the packets, two of the five test subjects stopped preparing their meal and put on their gloves for a few minutes.

(b) Rehydrating the dehydrated patties was difficult in the cold. Although an adequate amount of water was poured in the pouch, the patty did not rehydrate to a significant degree. The three test subjects who attempted to prepare and eat it left it after one bite.

(c) The cheese spread started to freeze in the cold and became increasingly difficult to manipulate. Much of the cheese was left unconsumed.

(d) Preparing and (partially) eating the MRE with the dehydrated component took an average of 21 minutes in the cold; the menu with the wet entree took an average of 16 minutes to prepare and eat. These times include the time spent putting gloves back on and trying to warm hands.

(e) In posttest interviews, test personnel suggested that in the cold they be given a ration consisting of one or two components -- perhaps a meal bar and a candy bar -- in packages that could be opened easily and in a form not requiring rehydration.

Heat conditions. The interview and climatic chamber tests revealed the following information on heat conditions:

(a) As in the cold condition, test subjects had difficulty opening the packages, particularly the outer package. Under humid conditions hands became very sweaty and the package kept slipping.

(b) In the heat, the cheese spread visibly deteriorated and the peanut butter separated. Both components were difficult to handle, and subjects commented that they looked unappetizing. In addition, the chocolate products melted.

(c) In posttest interviews, test subjects indicated that they felt that some of the components in the MRE were inappropriate for hot climates. They expressed a preference for more fruit, a "lighter" entree, and a non-chocolate dessert.

In summary, these laboratory investigations have several implications for ration design.

(a) Certain dehydrated ration components are limited in their usefulness in the cold, since they cannot be rehydrated in their frozen state using cold water and require warm or hot water to rehydrate.

(b) Problems in opening packages and manipulating contents are likely to be accentuated in temperature extremes where protective clothing or sweaty, slippery hands make the items more difficult to handle. This difficulty can result in increased preparation times.

(c) An all-weather ration system will need to take into account the effect of temperature extremes on the ease with which ration components can be prepared and consumed.

Convenience related issues (Arctic Ration Norway Test). A second evaluation involved Marines' reactions to the Arctic Ration. This ration system, under development for the Marine Corps at NRDEC, was tested during amphibious exercises conducted in Norway in March '84. As part of this test, a questionnaire was distributed to 143 Marines at the end of a 6-day period, during which these troops had been positioned in a forward operational area. During that time, the Arctic Ration had been their sole source of food. The survey included questions about ration convenience and eating habits in the field. The results are as follows.

(a) Troops were asked how satisfied they were with different aspects of the Arctic ration. A seven-point rating scale was provided, ranging from 1=Very Dissatisfied to 7=Very Satisfied. Taste, appearance, quantity, and variety of the ration were rated positively (greater than 4) on the average; however, ease of preparation was rated slightly dissatisfactory (average rating was 3.75).

(b) Troops were asked whether they got enough to eat during the 6-day portion of the exercise. Only one-third reported getting enough to eat; 36% reported being sometimes hungry, 22% reported being often hungry, and 9% reported being almost always hungry.

(c) In a related question, troops were asked to indicate which of several reasons accounted for their not eating enough during the exercise. The response frequencies were as follows:

| | |
|---|---|
| Not enough time to prepare ration | 52% |
| Too much trouble to prepare ration in the cold | 36% |
| Dislike the food in the arctic ration | 25% |
| Not enough time to eat ration | 25% |
| Not enough food provided in the ration | 25% |
| Too cold to stop and eat | 13% |
| Other | 18% |

The lack of time to prepare the ration and the trouble involved in preparing it were the two most frequent reasons reported for not eating enough during the excercise.

(d) Among five proposed improvements to the Arctic Ration, making the ration easier to prepare was considered the most important change, ahead of including more breakfast items, improving taste, increasing variety, and making the portion sizes larger.

(e) Troops were asked to rate how easy or difficult they found each of several aspects of preparing the Arctic Ration in the cold. The responses indicate that troops encountered difficulties in two areas: obtaining enough water to rehydrate the dehydrated components of their ration; and heating the water for purposes of rehydration. An additional inconvenience involved in rehydrating rations is the time required to rehydrate a component. The Arctic Ration specifies that the user must wait 10 minutes before an entree bar is rehydrated. Despite the problems with obtaining water there was no evidence that Marines experienced dehydration during the 6 days that they used the Arctic Ration.

(f) Troops were asked how many meals they usually ate a day. Forty-three percent reported eating only one meal a day, 38% reported eating two meals, and 20% three or more meals a day. Several small, but statistically significant correlations were observed between the number of meals eaten and the perceived convenience of the ration. Troops that considered the ration easy to prepare ate more frequent meals. Fewer meals were eaten by those that lacked the time to prepare the ration or considered preparation troublesome. This suggests that convenience influences not only how much is eaten, but also how often troops eat in the field.

(g) During the exercise, the only well-defined meal period appeared to be breakfast. Approximately 60% of the sample reported eating a meal between 6 AM and 8 AM. Thirty percent of the sample reported eating between 6 PM and 8 PM. While respondents tended to eat only one or two meals a day, snacking was common at all hours of the day and night, especially during the middle of the day.

(h) While on the move, 43% of the respondents carried only part of the Arctic Ration. Respondents were asked which of three reasons was the main reason they did not carry everything that came with the ration. For 30% of the troops, the main reason was that they disliked the taste of certain ration components; 12% said they wanted to save space and 5% said they wanted to save weight. Clearly, a large proportion of the troops were selective in what components they ate. Depending on the items omitted, a selective consumption of the ration could lead to nutritional deficits over prolonged use of the ration.

(i) The components of the Arctic Ration are packaged in two outer bags, one bag containing the entree bars and beverage packets, and another bag containing desserts and candies. Most (77%) of the troops opened the outer bags and carried the individual items separately, probably distributing the components between backpack, jacket and pants pockets. This suggests that ration components be designed to fit conveniently into those various spaces, since the outer bag does not constitute a functional unit when the ration is carried by the troops.

In conclusion, while the Arctic Ration was generally well accepted, the ease of preparing the ration was rated somewhat negatively. The importance of the convenience factor is evident in that, for over 50% of the Marines, the lack of time to prepare the ration was a reason for not eating enough. Convenience also appeared to influence the number of meals eaten.

Troops reported difficulties with rehydrating the dehydrated components of the ration. Water was somewhat difficult to obtain and heating it was also somewhat difficult. Past results have repeatedly indicated that troops encounter difficulties in obtaining enough water for rehydration in the cold.[9,10]

Troops tended to eat between one and two meals a day on the average, and, except for breakfast, meal periods were not well defined. Troops appear to eat as time permits, often only a snack. A previous study[11] has suggested that the lack of well-defined meal periods may have been a contributing cause to the weight loss observed during prolonged use of the MRE combat ration. This suggests that greater emphasis may be needed on providing structured meal periods when operational rations are used.

General conclusions. As a result of these varied customer surveys and field reports, a number of basic design concerns surfaced. Specific concerns included rations that freeze, require preparation, require hot/boiling water to heat, are not conducive to eat-on-the-move situations, are inconvenient to carry, are difficult to open, and require the availability of water for main meal consumption. As it was beyond the scope of this project to go into the field and quantitatively determine, through the end-user, the level of concern relative to each of the above issues, conclusive data to label these concerns as significant design deficiencies are unavailable. Under these circumstances, it was determined that the most prudent course of action was to treat these concerns as positive design opportunities that could only contribute in the final analysis to providing the individual combat Marine with the most convenient and acceptable ration possible.

## Nutritional Design Considerations

While not a direct issue in the development of the ration itself, the project participants were concerned as to the nutritional well-being of the Marine as he enters into a precombat condition. In light of the rapid response potential of an amphibious assault, the overall subsistence pattern of the combat Marine was reviewed. Figure 3 illustrates the typical scenario where the Marine might move from an A-Ration garrison (ashore) facility to an A- or B-Ration shipboard (afloat) facility, deploying then into combat using operational rations (either individual or group). Depending upon the particular mission of the task force, the Marines may then reboard the amphibious ships - move - and strike again, or return to a base station.

Garrison/Off Base
↓
Shipboard
↓
→ Assault Phase
↑ ↓
← Shipboard

Figure 3. Subsistence pattern.

In the initial phase, given that attendance for garrison feeding is often voluntary and the selection of foods eaten is purely discretionary, the Corps, in effect, relinquishes control of a potentially key readiness factor. Onboard ship while the Marine is in transit and faced with the monotony of shipboard living, maximum participation in meal service seems more ensu ed. Control over subsistence is once again lost as the Marine becomes engaged in combat. The issue of this variable subsistence pattern is raised purely to call attention to this sometimes neglected and overlooked element of combat readiness. Admittedly, many of the effects of nutrition on the performance of the combat Marine are subtle and difficult to evaluate. Nevertheless, it was felt that any potential for ensuring or possibly enhancing the combat effectiveness of the Marine in this regard should be investigated. As a result, a broadbase nutritional literature search was initiated over concerns regarding the casual subsistence patterns and performance implications to the Marine in precombat, combat, and postcombat situations. The purpose of this search was to investigate nutritionally oriented proactive approaches for maintaining or enhancing the effectiveness of the Marine in combat. Conclusive indepth research into these areas was, however, considered beyond the scope of this project.

The following is a brief discussion of the more significant topics and approaches identified in the search as worthy of further investigation. A more detailed analysis of all involved nutrients can be found in Appendix D.

Of particular interest was the expanded use of carbohydrate food forms in the diet. Menus could be developed to provide more carbohydrates while maintaining high customer acceptance. Carbohydrate-enhanced A- or B-Ration menus would be provided to embarked (shipboard) Marines for approximately 72 hours prior to an assault, and again in the postassault phase once the combat situation had stabilized. Carbohydrates with low glycemic indices would be preferred. Additionally, elements of this diet are already available in shipboard subsistence inventories. This approach offers a number of positive features: 1) in the infrequent situation where a Marine had not achieved glycogen saturation prior to combat, this menu would be of assistance; 2) the typical dietery myth that high protein meals are what will "help me perform at my peak" would be circumvented; the Marine would automatically get what benefits him most going into combat; 3) given the nature of the amphibious assault and the likelihood that little or no food will be consumed for many hours after debarkation, this menu would provide the optimal energy source; 4) once the combat situation stabilizes to the point that A- or B-Ration carbohydrate-enhanced menus can again be offered, such menus will replenish glycogen stores faster than other alternative menus.

The concept of carbohydrate-enhanced rations carries over into the design of the amphibious ration. By offering smaller meals of this nature at more staggered intervals throughout the day (four per day vs three), a Marine's energy level would be more consistently maintained during combat.

A second research consideration is the substitution of some percentage of protein for carbohydrate in the Military Recommended Daily Allowance (MRDA).[12] Among other things, this would help to conserve water. A reduction in protein related calories in the MRDA from 11% to 9% could save possibly as much as 8 oz. of water required in the metabolization and waste processing of this material. While this amount of water may seem inconsequential it should be remembered that water availability in the field can be a problem, particularly in the early-on stages of an amphibious assault. No conclusive evidence could be found in the literature to support protein levels over the USRDA requirement. As for the AR 40-25 position regarding protein and diet acceptability researchers felt that the acceptability of the end item is far more reliable a factor in ensuring ration consumption than the quantities of protein provided. While half of the proposed ration will be an entree (meat-type) bar, the make-up of this manufactured food form would allow for holding the actual protein in the bar to whatever level was desired. By ensuring a high quality, high preference food item that is both flavorful and optimally textured, the researchers felt the end-user's acceptance of the ration would be uninfluenced by whatever actual protein level had been established in the bar.

Caffeine became a concern to researchers in that withdrawal symptoms from heavy use i.e., three or more cups of coffee per day, could cause undesired side effects for the combat Marine. With the ready availability of brewed coffee aboard ship and the potential for a complete withdrawal upon debarkation and into the early phases of an assault, the possibility exists of headaches, irritability, inability to work effectively, nervousness, restlessness, and lethargy all occurring in varying degrees between 12 and 36 hours after the last caffeine dose.

Citing reduced intake levels of vitamin A in two separate studies, the project participants questioned the potential impact of these deficiencies on the Marines' night vision capabilities. See Appendix D. Given the lack of broad-base popularity in garrison feeding situations of many of the better sources of vitamin A, and given the long lag time required to make-up for such deficiencies, particular concern exists in situations calling for the rapid projection of Marine forces into geographic areas that dictate greater nighttime activity. Relying on operational ration contributions of vitamin A once the marine is engaged in combat could mean weeks of impaired night vision, depending on the individuals precombat deficiency level.

In addition to the above topics, references pertaining to the importance of adequate water availability, the effects of chemical- and biological-induced stressors on the body, and the significance of vitamin C, electrolytes, iron, zinc and thiamin can be found in Appendix D.

Analytic Evaluations

In the overall design of this concept the capability of providing a low volume ration was considered to be highly mission supportive. As such, a ration volume reduction analysis was initiated and carried out in two parts.

In part one, the three current ration systems were evaluated. The objective was to determine a benchmark weight and volume level for each respective system. This analysis would additionally be carried out at three differing caloric levels: 1) 3600 Kcal (temperate climate); 2) 4000 Kcal (hot/arid climate); and 3) 4500 Kcal (cold climate). Part two of the analysis involved the evaluation of several amphibious ration system concepts. The objective in this case was to assess the potential for volume reduction from a number of perspectives. Results from this analysis would then be used to establish "target design goals" relative to weight and volume in the new ration system.

Part one commenced with the collection of data regarding the three current operational ration systems: the Food Packet, Long Range Patrol (LRP); the Food Packet, Assault (FPA); and the Meal, Ready-to-Eat (MRE). This required documenting 84 food and sundry components that make-up the 3 systems. Analysis of the components was then conducted to determine weight and volume data. This was performed at the net level (no packaging), at the intermediate level (item packaging), and, lastly, for the fully packaged, off-the-shelf items.

It should be noted that in determining an appropriate sample size considerable resources were expended to derive the weight/volume characteristics of, and to compile data for this one sample alone. The desirability of a statistically valid sample size had to be assessed both in terms of its potential contribution to the overall effort as well as its costs. In this regard, it was determined that the marginal utility of obtaining an expanded sample was not justified.

As part of the overall analysis, nutritional values for each food component had to be calculated. Since a "Record of Nutritive Values"[13] was already available for both the LRP and the MRE, macronutritional (i.e., carbohydrates, fats, and proteins) and micronutritional (i.e., vitamins and minerals) values were simply calculated from this on a net weight basis. In the case of the Assault Packet (AP) which was still in the developmental stage, only approximate macronutritional data were available. Micronutritional breakdowns would not be available within an appropriate timeframe for inclusion in the analysis. For both the MRE and LRP, macro/micronutritional values were averaged in the following manner:

$$\frac{\text{OSACO measured net weight}}{\text{"Record of Nutritive Value" net weight}} \quad \begin{matrix}\text{macro/micro}\\ \text{component}\end{matrix} \quad = \quad \begin{matrix}\text{Averaged component}\\ \text{nutritive value}\end{matrix}$$

These component values were then refigured back into their respective menus. Finally, mean values were calculated for off-the-shelf (total ration) weight, volume, and calories.

Having established this baseline data at both the individual component and total packaged ration levels, the analyst then focused on comparing ration weights and volumes by climate. It should be noted that the three rations are not necessarily being compared in a manner for which they were designed. Each has been designed to support a specific type of mission. Further, the MRE is the only true ration by definition, the AP and LRP are both food packets. A final word of caution pertains to references throughout the study to the differing calorie requirements in hot and cold geographic areas. These requirements have not necessarily been established as a direct result of the climate. In the case of the cold weather requirement for example, the 4500 Kcals relate more to such variables as the Marines' carried load, mobility (skies, snowshoes), and sheltering/subsistence alternatives. The three climate levels are used throughout the analysis as real opportunities do exist for the combat Marine to deploy to these diverse areas.

Recalling that 3600, 4000, and 4500 calories are required in temperate, arid, and cold climates, respectively, the following ration system weights and volumes were calculated as shown in Figures 4, 5, and 6. As can be seen, MREs do best at

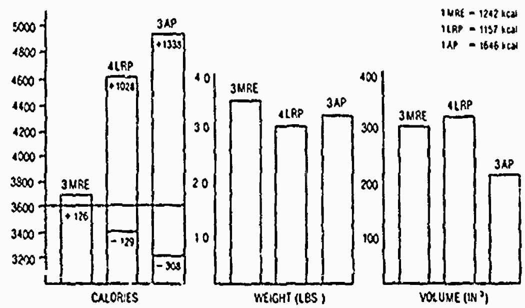


Figure 4. Comparative calories, weights, and volumes of rations (3600 calorie level).

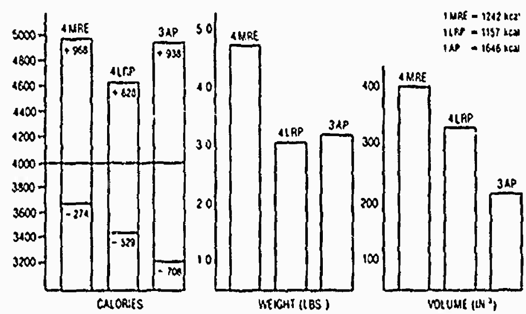


Figure 5. Comparative calories, weights, and volumes of rations (4000 calorie level).

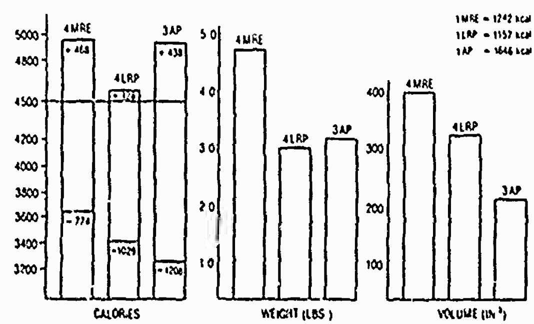


Figure 6. Comparative calories, weights, and volumes of rations (4500 calorie level).

meeting the calorie requirement for temperate climates. However, considering the excess calories provided in offering four LRP's and three AP's in order to meet the 3600 Kcal requirement, the MRE, on a comparative basis, does not do nearly as well as the LRP and AP in regards to weight and volume efficiencies.

It should be noted that in all cases the number of calories needed to meet a specific requirement have been rounded up to the nearest whole ration. In some instances where the number of calories falls only slightly short of the requirement, this approach may appear severe. However, it was felt that if AR 40-25[12] cites a specified calorie level then it should be met.

None of the ration systems do well in responding to the 4000 Kcal hot/arid requirement. While not designed as such, the LRPs do well in meeting the 4500 Kcal requirement. The LRPs do, however, carry with them a significant volume penalty. Overall, it can be seen that currently available options offer the MAGTF Commander little flexibility in selecting a single ration system that is responsive to the varied requirements for global operations.

Part two of the analysis explored various concept design alternatives, relative meal size, menus, etc. In addressing the issue of meal size, both from the perspective of geographic versatility and end-user benefits, it was felt that since combat is not a neatly structured "9:00 to 5:00" experience, adherence to the traditional three-meals-per-day concept of feeding could be questioned. What then, is a more useful configuration? As one example, using the largest common factors' product as a quantitative guide for determining optimal meal size, it can be shown that:

$$\begin{aligned}
3600\text{ Kcal} &= (2^2)(2^2)\ (3^2)\ (5^2)(\text{N/A}) \\
4000\text{ Kcal} &= (2^2)(2^3)\ (\text{N/A})(5^2)(5) \\
4500\text{ Kcal} &= \underline{(2^2)(\text{N/A})(3^2)\ (5^2)(5)} \\
& \quad (2^2) \qquad\qquad (5^2) \qquad = 100\text{-Kcal sized meals}
\end{aligned}$$

As can be seen, the optimally sized ration would have the Marine trying to handle 36 100-Kcal meals per day in the field. Since this is unacceptable, a best fit was then sought between the extremes:

$$\begin{aligned}
3600\text{ Kcal} &= (2^2)(2^2)\ (3^2)(5^2)(\text{N/A}) \\
4500\text{ Kcal} &= \underline{(2^2)(\text{N/A})(3^2)(5^2)(5)} \\
& \quad (2^2) \qquad (3^2)(5^2) \qquad = 900\text{-Kcal sized meals}
\end{aligned}$$

This established the number of required menus at four in temperate climates and five in cold climates. Additionally, it was noted that four and one-half of the 900-Kcal modules would provide 4050-Kcal per day, or 1% over the 4000 calorie arid climate requirement. Thus, if a basic 900-Kcal "module" were configured into coequal (450-Kcal) "submodules", a responsive and convenient-to-handle ration system would result. The issuing of a submodule (450-Kcal) would be necessary <u>only</u> in an arid climate and <u>only</u> when missions/resupply cycles consisted of an odd number of days.

Although the design requirement to minimize volume could have been more easily met through the construction of a model, it was strongly felt that such hypothetical solutions should be assessed in terms of real world considerations to the maximum extent possible.

A second comparative analysis involved examining off-the-shelf weights and volumes to the weight and volume totals of the individual components. Below is a summary of that analysis:

TABLE 8. Ration Packaging Comparisons.

| | MRE | | LRP | | AP | |
|---|---|---|---|---|---|---|
| | gm | % | gm | % | gm | % |
| Off-The-Shelf Weight[a] | 496 | | 319 | | 458 | |
| Total Intermediate-Packaged Weight[b] | 466 | | 303 | | 442 | |
| Difference | 30 | 6 | 16 | 5 | 16 | 3 |
| | cc | % | cc | % | cc | % |
| Off-The-Shelf Volume[a] | 1633 | | 1335 | | 1171 | |
| Total Intermediate-Packaged Volume[b] | 861 | | 519 | | 435 | |
| Difference | 772 | 47 | 816 | 61 | 736 | 63 |

[a]Weight and volume of the unopened ration.
[b]Total weight and volume of the individual components within the ration.

As can be seen, there are relatively little weight differences while substantial differences in volume exist. The optimal approach to minimize these differences and maximize volume efficiencies is to standardize the lengths and widths of the components. Using a tight-fitting overwrap, the new total volume would have to be only slightly larger than the sum of the components.

In summary, the analysis of the current ration systems provided both baseline weight/volume data for later comparative analysis and identified two key design objectives for the amphibious ration: 1) the need for caloric responsiveness (adjustability) in terms of the three climates; and 2) volume reduction through the standardization of component lengths and widths within a tight-fitting menu overwrap.

In selecting the optimal quantitative technique, it was recognized that by concentrating on the elements of calories and macronutrients, the volume minimization requirement could be reduced to the following form:

| Factors | Daily Requirement | Modular Equivalent |
|---|---|---|
| Volume (cc): | Minimize | Minimize |
| Calories | 3600 | 900 |
| Protein (g) | 100 | 25 |
| Fat (g) | 160 | 40 |
| Carbohydrate (g) | 440 | 110 |

In evaluating the calories supplied by the various ration components, it can be seen that rank ordering by weight vs. rank ordering by volume produces different ordered listings (See Table 1).* Since one ranking is not necessarily a good indicator of the other, and since the design emphasis is on volume reduction, caloric density based on volume became the basis for this analysis. As can be seen from the data previously presented in Table 1, the more components that are used in designing a ration system (ties in volume with different mixes notwithstanding), the greater the drain on the volume efficiency of that system. Thus, the pursuit of volume minimization suggested the following augmented definition for menus; where a given menu is composed of component set "x" for the second through sixth alternative menus, no set may consist exclusively of "x" components. Because certain macronutritional requirements have to first be unconditionally met, the "mixes" or types of each food used in designing the ration will not always be the most volume efficient foods. Additionally, Table 1 does not specify the appropriate quantities of foods for an optimal mix, however, a quantitative technique that would accomplish all the above requirements is mathematical programming.

Since nutritional and caloric constraints are linear in nature, the specific allocation model known as Linear Programming (LP) was chosen to optimize both the mix and quantities of product selected. In terms of this ration design effort, the program can be stated as such:

| | Factors | Daily Requirement | Modular Equivalent |
|---|---|---|---|
| Objective Function: | Volume (cc) | Minimize | Minimize |
| Constraints: | Calories $\geq$ | 3600 | 900 |
| | Protein ($\bar{g}$) = | 100 | 25 |
| | Fat (g) $\leq$ | 160 | 40 |
| | Carbohydrate (g) $\geq$ | 100 | 25 |

Having constructed the program, it remained only to establish a data base of candidate foods from which to begin building the amphibious ration menus. While certain inherent deficiencies were recognized in the use of components from the current ration systems, the fact remains that data on these components were readily available on what is a rather unique family of food products. Additionally, since these components were already elements of existing systems, some of the design characteristics that researchers sought to optimize (i.e, reduced volume, extended shelf life, etc.) were presumed inherent in some of their designs.

It should be noted that the LP-generated menus, using components from all three existing systems, are for illustrative purposes only. The analysis merely serves to establish a "target goal" for volume in the prototype ration. It was felt that if some level of volume reduction could be achieved using existing ration components, then the proposed intermediate moisture products could be designed along similar lines. This comparison issue surfaces again in the menu generation analysis where, for example, large amounts of a chocolate bar are selected to minimize volume. This selection is not to suggest that the Marine would eat all of this item - the chocolate is merely an example of the products composition that can then provide an example in the design of any new components for the ration.

*A more comprehensive ordering of components can be found in Appendix E.

If a single menu had been all that was required, it would have remained only to run the Linear Program (LP). However, the parallel objectives of volume minimization and menu variety were not consistent with the nature of conventional LP applications; that of finding the one optimal solution to a given problem for a given data base. The network approach, however, finds a "next best solution" by separately deleting each component in the initial solution, then rerunning the program. Each mix, or group of items representing a hypothetical menu, consists of the components required to optimize the objective function as well as their "activity levels" (that is, the amounts of each component required for optimization). Thus, in minimizing the volume of multiple menus, it is not the value of a single objective function that is of concern but that of the overall system. While the network approach produced menu volumes that were quite small, a literal interpretation of the term "minimum" would be deceiving.

Figure 7 begins with the initial data base of all components. Directly beneath is the objective function value resultant from running the LP with this data base, followed by variable mix* components that produced it.** Note that subsequent to this run of the initial data base, beef jerky, caramels, and chocolate candy (the three components of this variable mix) were then, in turn, excluded from the data base in subsequent LP runs. The objective functions from each of these runs were then compared. The deletion of caramels produced an objective function smaller than either of the alternatives, thus menu #2 was identified. Subsequently, the three components of menu #2 were each similarly removed from a data base initially consisting of all components except caramels. This "network" process continued until an objective function larger than at least one of the original alternative branches was encountered (not shown in Figure 7). At this point, an alternative branch's mix became the next menu. The process continued until six menus were generated.

Note that the objective functions of menus #4, #5, and #6 are equal. These are referred to as "ties" since their mixes are different. In the case of "twins", the tie would result from duplicate deletions, and therefore produce identical menus (thus, no menu variation).

Theoretically, a multivalent run of the LP that would simultaneously produce six menus would result in a system with a smaller average volume than that previously achieved. In considering a method by which this might be accomplished, two points of interest should be noted. First, the optimal solution (to menu #1) does not change with respect to different methodologies for the generation of subsequent menus. Differences in average volume that do result from alternative methodologies come about exclusively as a result of volume differences in the second through nth menus.

Second, as either the range between the first and last menu volume narrows and/or the dispersion (clustering) among menu volumes tightens, volume reduction by alternative methods is largely theoretical and not necessarily translatable into any real world improvement. In other words, the differences, in some cases,

*"Final" variable mix is a standard term utilized in LP. However, to avoid confusing jargon, the terms "variable mix", or simply "mix", shall be employed in place of the standard terminology.

**For clarity's sake, other output such as activity levels has been omitted from Figure 8.

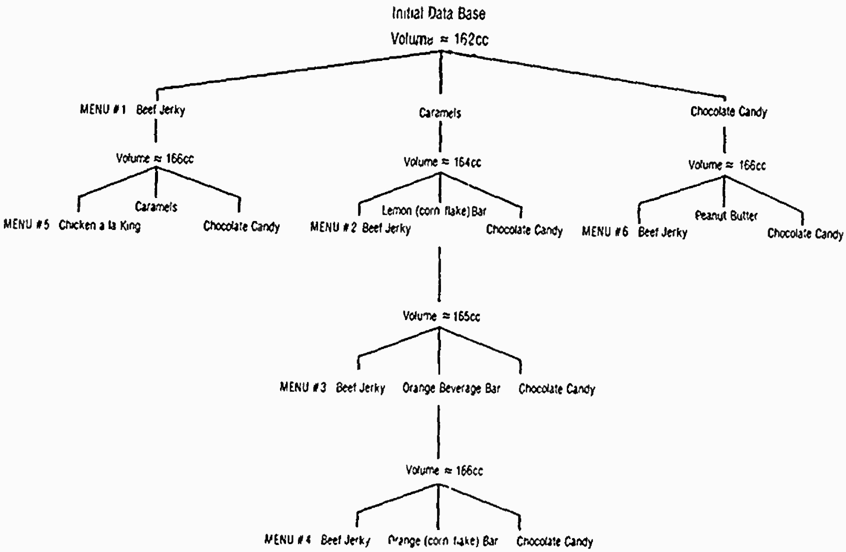


Figure 7. Menu component selection.

are too minute to deal with in a real world manufacturing process. Nevertheless, since the determination of what constitutes "narrow" or "tight" is relatively subjective, the researchers experimented with a more theoretically satisfying model.

One obstacle in developing the model was that without some change in either the original data base, and/or the program, the LP precluded any menu variation. Since alteration of the data base had already been utilized, efforts focused upon revising the original Linear Program.

To accomplish the reprogramming, two questions had to be addressed. First, which additional components (in addition to those provided by the initial variable mix) should be introduced into the revised menu cycle; and second, to what levels of activity should such components be constrained? The first question was simply resolved, since the network process itself had already indicated an order of preference among the components. For example, assume (through the network approach) that the first mix consisted of components A and B that the second lowest volume mix consisted of components B and C. Therefore, if component A did not exist, the optimal mix would be B and C without any necessity for reconstraining. In short, component C enters the mix "naturally" and is thus the most compatible component in terms of complementing the initial mix.

The second question of Right Hand Side (RHS) constraints is more difficult, since it rests, in part, upon the subjective determination of what constitutes an "adequate" activity level in terms of the real world's manufacturing capabilities. The new program could consist of:

| | | |
|---|---|---|
| Minimize | : | Volume |
| Calories | : | $\geq 3600$ |
| Protein | : | $\geq$ 100g |
| Fat | : | $\leq$ 160g |
| Carbohydrate | : | $\geq$ 440g |
| Component C | : | $\geq$ 0 |
| (in original units)* | | |

As an example, assume the constraint becomes component C $\geq$ .001, and component C is equal to 850 cc (roughly the size of a carton of cigarettes); a run of the LP would specify .85 cc of component C, which is a volume equivalent to 1% of the size of a package of cigarettes. Obviously, such solutions are purely theoretical; however, constraining RHS to produce more "acceptable" real world results would automatically violate the paramount objective of absolute volume minimization. As such, any further use of the term "minimized" volume will be something of a misnomer, and the term is used only in the relative sense of being the smallest volume possible given a minimum acceptable component volume.

## Alternative Design Concepts

To assist in developing what would become the preferred ration concept, the following design objectives were reintroduced for general guidance purposes.

- Reduce the carried load and/or extend mission endurance (relative to subsistence).
- Tailor the ration design to the combat uniform.
- Offer only those items with the highest and most broadbase customer appeal.
- Limit total number of menus in the ration system.
- Minimize the total number of ration components.
- Emphasize item quality over item variety.
- Provide the most convenient-to-use ration practicable. Food forms should be consistent throughout the ration system (i.e., do not mix wet meat entrees with dehydrated compressed entrees). Food items should require no preparation other than to open and eat. No utensils should be required to prepare or eat the ration.

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*Programming nonattractive components by original units was found to be the most expeditious approach. However, setting up the constraint in terms of some other common denominator (e.g., volume) does not alter the inherent nature of the problem.

- The ration should have self-heating (exothermic) capabilities.

- There should be no dependence on canteen water to prepare or eat the food components.

These design objectives were seen as being both highly supportive of the individual combat Marine, but not contributing to the over-design of the ration.

An extensive listing of alternative subsistence concepts, some completely blue-sky in nature, were identified for initial consideration (see Figure 8). Each alternative was evaluated relative to the previously outlined design objectives.

- "Wet" Foods
- Dehydrated Foods
- Dehydrated Compressed
- Intermediate Moisture Foods
- Liquid Diets
- Dehydrated Diet Supplements
- Pill Form
- Time-Released Nutrients
- Intravenous/Epidermal
- Nutritional Snack Bar
- No Individual Rations

Figure 8. Alternative subsistence concepts.

"Wet" food alternatives such as those found in the MREs were investigated. While representing a convenient, highly acceptable form of food they were found lacking on two counts; the first being the potential for freezing in cold climates, and the second a generally less than desirable Kcal/cc ratio, which would effect volume.

Dehydrated and dehydrated compressed items were considered less desirable for the following reasons: 1) a dependence on canteen carried water to reconstitute the food items (or to drink while eating dry); 2) the time required for reconstituting the meal, and; 3) difficulties in reconstituting the product using cold water (at 45°F or less).

The general concept of intermediate moisture foods was found to satisfy a number of the design objectives.* They were convenient to use (open and eat), required no preparation, no water to reconstitute, were calorically dense (hence the conservative volume), and to a limited degree resisted freezing.** Potential product development (R&D) problems were identified at the laboratory level. This is not to say that these products exist, as envisioned, today. Since end-user considerations, not available technologies, were the driving considerations in the evaluation, the concept of intermediate moisture foods remained a viable option.

*See Appendix B "Intermediate Moisture Foods - A Brief Review."

**These are selected characteristics from what is a very large general classification of food items.

Convenient-to-use liquid dietary preparations and fortified puddings similar to those used in hospital settings were evaluated. The concept was discouraged due to poorer than expected Kcal/cc ratios.

Dehydrated dietary supplements such as dental liquid diets and many retail off-the-shelf preparations were rejected primarily due to a dependence on canteen water for preparation.

The concept of providing 3600 Kcal a day in pill form was investigated. As an example, vitamin pills were substituted by weight to approximate MRDA carbohydrate, protein and fat contributions. This is of course a crude approximation in that it considers the pills to be of equal make-up as the fats, CHO's and protein. Nevertheless, it took over 700 pills to make up the 3600 Kcal energy requirement. Ironically, all of the vitamins and minerals were contained in only one pill. While the number of pills could be reduced by increasing the percentage of fat-related calories and/or by increasing the pill size to 00, the overall concept was dismissed as impractical. Unless hundreds of future generations of Marines evolve to metabolize other (higher) forms of energy - today's ration designers are locked into some irreputable realities in regards to human physiology (see Table 9).

TABLE 9. Energy Yield From Oxidation of Pure Substances.

| Substance | Heat of Combustion cal. per 100 grams |
|---|---|
| Glucose | 371 |
| Sucrose | 395 |
| Starch | 418 |
| Glycerin | 431 |
| Ethyl alcohol | 711 |
| Palmitic acid | 931 |
| Stearic acid | 948 |
| Benzene | 1000 |
| Octane | 1140 |
| Hydrogen | 3390 |

The use of time-released and/or encapsulated nutrients is appealing, particularly in the case of carbohydrates and certain water soluble vitamins - especially if these intakes are infrequent now. As mentioned before, the proposed amphibious ration will be made up of smaller quantities of food that will be consumed more frequently, to some degree duplicating the potential benefits of time-release nutrients.

Any consideration of intravenous or hypoalimentation feeding was dismissed. Two of the numerous reasons centered on the practicality of such feeding in a combat situation and the fact that such methods require administration by trained medical specialists. Patch-type (epidermal) feeding was not possible due to the impermeability of the basic energy materials through the skin.

High calorie nutritional (snack) bars were considered an attractive alternative. If it were not for the objective of trying to maintain a single ration logistics system, the prospect of using such food bars in the first 24 to possibly 72 hours of an amphibious assault operation would be most appealing.

One final alternative, or perhaps a future reality, is the possibility of having no individualized ration systems, as they exist today. Escalating costs may see the services as more reluctant to use individual operational rations in training exercises. The irony of this situation would be that as demand goes down unit costs would increase even higher.

As previously mentioned, a further objective was to minimize the number of components in each menu to simplify handling (preparation/eating) in the field. As the entree and fruit portions of existing rations were typically rated the most favorable among the various ration components, these items became the basis for the menu concept. Again, until such time as more conclusive tests can determine, for example, that one item in some particular number of flavors would be acceptable for up to 15 days in combat, or that possibly three types of foods were needed in some particular variety for this period, then decisions such as this can be based on convenience-related issues or other criteria deemed important. Table 10 illustrates the number of components in the existing ration systems and the number that is optimistically proposed for the new ration.

TABLE 10. Ration Components.

| RATION | COMPONENTS | TOTAL |
|---|---|---|
| MRE | 5 Primary Food Items<br>1 Secondary Food Item<br>1 Accessory Packet (9 Items)<br>1 Spoon | 16 |
| Assault Packet | 6 Primary Food Items<br>1 Secondary Food Item<br>1 Accessory Packet (7 Items)<br>1 Spoon | 15 |
| LRP | 2 Primary Food Items<br>1 Secondary Food Item<br>1 Accessory Packet (6 Items)<br>1 Spoon | 10 |
| Prototype Amphibious Ration | 2 Primary Food Items<br>1 Accessory Packet (5 Items) | 7 |

The following menu combinations seen in Table 11 are examples of meat and fruit items having high, broadbase population appeal. The intent here is merely to illustrate popular flavors that might possibly be used in neutral based intermediate moisture food bars.

TABLE 11. Prototype Menu Options.

| | Mean[a] Rating | Percent Tried | | Mean[a] Rating | Percent Tried |
|---|---|---|---|---|---|
| Grilled Steak | 7.76 | 98.3 | Fried Chicken | 7.38 | 98.7 |
| Watermelon[b] | 7.08 | 97.6 | Tangerines[b] | 6.90 | 95.1 |
| French Fried Shrimp | 7.13 | 93.0 | Pizza | 7.04 | 98.8 |
| Grapes[b] | 6.89 | 98.9 | Apples[b] | 7.12 | 99.0 |
| Spaghetti w/Meatballs | 7.17 | 98.4 | BLT Sandwich | 7.24 | 97.7 |
| Pears[b] | 6.84 | 97.5 | Fruit Cocktail | 6.43 | 96.7 |
| Roast Beef | 7.04 | 98.2 | Cheeseburger | 7.00 | 99.1 |
| Canteloupe[b] | 6.85 | 93.0 | Bananas[b] | 7.86 | 98.0 |
| Roast Turkey | 6.96 | 99.3 | Swiss Steak | 6.94 | 96.6 |
| Oranges[b] | 7.14 | 98.7 | Strawberry Shortcake | 7.43 | 98.0 |
| Barbecued Pork | c | c | Baked Ham | 6.82 | 98.7 |
| Peaches[b] | 7.16 | 97.7 | Apple Pie | 6.98 | 98.0 |

[a]Ratings are from Meiselman, H.L., Waterman, D., and Symington L.E., Armed Forces Food preferences. U.S. Army Natick Development Center, December 1974 (AD A110 512). Ratings are based on nine-point hedonic scale.

[b]Refers to fresh fruit except fruit cocktail (canned).

[c]Mean rating for Barbecued Spareribs = 6.84; for Barbecued Beef Cube = 6.13; Barbecued Pork per se was not rated.

## Preferred Concept

As a result of these evaluations, the preferred concept developed for the amphibious ration, is as follows.

The concept's basic food form is an intermediate-moisture-type food product that provides the end-user with a readily consumable item requiring no preparation or canteen water to reconstitute. The product lends itself well to eat-on-the-move situations and is manufactured such that free water is bound to protein, fats, or carbohydrates. This design offers protection from physical changes due to below freezing temperatures, as in the Rich's line of frozen desserts that remain soft and can be eaten as is at 0°F temperatures (see Appendix A). As an added benefit, the low water activity also inhibits microbial growth. The product would additionally be shelf stable.

The ration consists of up to six 900-Kcal menus. This configuration offers the optimal fit under current climate requirements (see Figure 9). The proposed components are a 450-Kcal entree (meat type) bar and a 450-Kcal fruit bar. This configuration has additional paybacks in that during combat, as was shown, the larger-sized meals are at times not eaten in their entirety. The smaller meals may have a greater likelihood of being completely eaten. Given the 24-hour-a-day nature of combat, a Marine's energy level may remain more constant if he consumes over time four smaller meals rather than three larger ones. The total number of menus would initially be limited to six until further research into the correlation between quality and variety as they affect customer acceptance can be better determined.

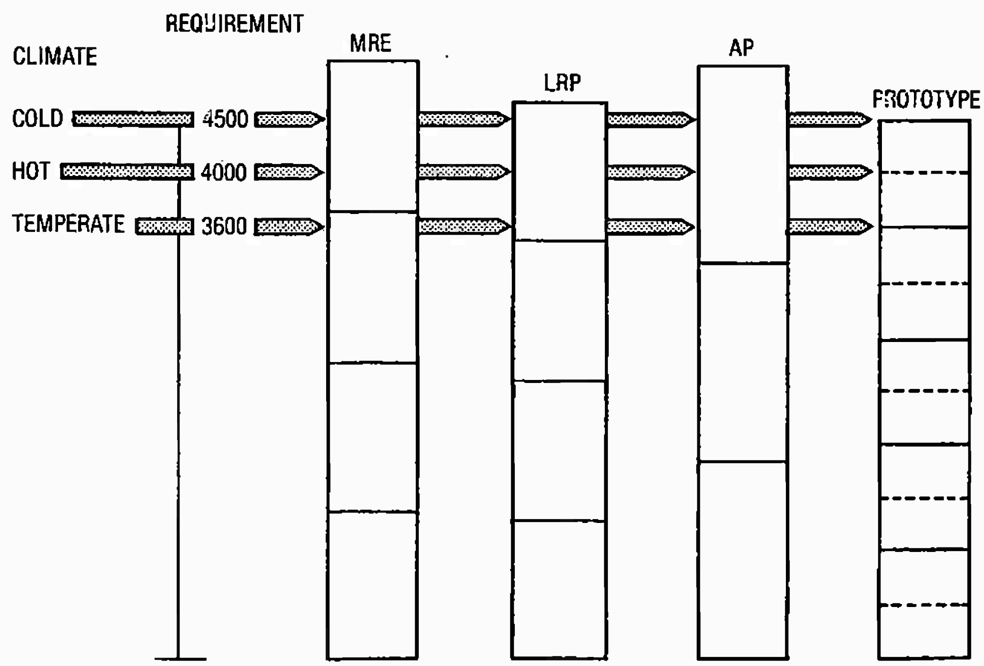


Figure 9. Modular design alternative.

The food items could optionally be eaten as-is or heated through a chemical reaction. The intent would not be to raise the temperature of the product to a specific level from any ambient temperature, but to provide a sufficient amount of heat to raise the temperature of the item by some predetermined number of degrees. This would likely focus on providing sufficient Btus to raise the product temperature from say 0°F (an extreme case) to perhaps 80°F to 100°F, achieving at least a warming of the food for the individual. Applying this process to heat water for beverages, while desirable, is very speculative at this time. Hot water for beverages would most likely have to be provided in a more traditional manner using a canteen cup. This use does not compromise the planned eat-on-the-move capability as it was never envisioned that this concept include a hot beverage. Canteen water would be consumed, as is now, on a regular basis or perhaps supported by an insulated container of a hot beverage that had been prepared at an earlier more convenient time. Appendix C contains one example (through a patent held by Ralston Purina) of exothermic product heating. At our request, this literature was reviewed by two in-house experts. Their conclusions (contained in Appendix C) were that this process was not adaptable for human use. With due respect for these findings, it is felt that the potential benefits of perfecting such a self-heating capability, i.e., no ancillary heating equipment, warrant a far more exhaustive analysis of this and similar methods.

Packaging would be of plastic/foil laminate design to offer protection against CB contamination - however, as previously stated, providing CB protection at the case level appears infinitely more practical and cost-effective.

The accessory packet, as envisioned, would contain three compressed beverage tabs (two hot drinks, possibly coffee and cocoa, and one fruit flavored drink), concentrated nutritive sweetener, and compressed creamer. These would be sealed into an extended flap on either component (see Figure 10). Spoons would not be required for meal preparation or consumption - a plastic stirrer could be provided for the hot drinks, if deemed necessary. Matches also, would not be provided as a standard part of the ration. Improved alternative material should be investigated to replace the toilet tissue currently used. Additionally, the supply should be packaged as flat as possible to approximate the length and width dimensions of the food components.

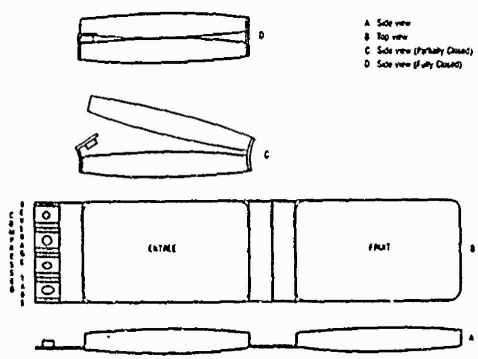


Figure 10. Proposed 900-Kcal ration.

The rations would be designed for easy storage on the combat uniforms. As uniform pocket storage is perhaps the most limiting option the Marine has at his disposal to carry food, this factor appeared to be the most practical approach to ration sizing. Each 900-Kcal module will be designed so as to fit into the combat uniform. After evaluating the various uniform pocket sizes and the required amounts of food to make up 900-Kcal, it was estimated that each module would approximate 13.9 cm L x 7.9 cm W x 1.98 cm D in size. While a tight fit, this size should allow for up to two rations to be stored in the smaller pockets. Each of the two packaged food bars would therefore average 13.9 cm x 7.9 cm x .99 cm in size. It should be reemphasized at this point that these are theoretical estimates to provide the developer with challenging design requirements.

Summary

As previously mentioned, concern exists as to the overall subsistence pattern of the Marine. Precombat (garrison feeding) evaluations should periodically be conducted to assess the nutritional profile of the Marine. Education through customer awareness is stressed at all stages of feeding, from pre- to post-amphibious assault, as the most cost-effective method of achieving nutritional objectives.

As a result of designing for optimal customer convenience in varied operational situations, the research team selected an intermediate food product as the basis for the ration. This two part, 900-Kcal ration would be adaptable under all climate extremes and require no preparation to eat. The ration consists of an entree and fruit component and menus are limited to six. The ration's dimensions will be tailored to the combat uniform. The target design weight and volume for each 900-Kcal amphibious ration module will approximate 200 cubic centimeters in size and 225 grams in weight. For comparative purposes this roughly translates into a 84% volume reduction and a 40% weight reduction over the MRE. Optimally, mission endurance relative to subsistence volume could be extended, if so desired, by a factor of six or, in this case, by the more restrictive weight constraint by a factor of 1.7. Additionally, these reductions could have a favorable impact on both the cost and complexity of logistics load management.

## IV. PROJECT SUMMARY

Throughout the project, the principal design considerations were to develop a ration system stressing maximized convenience of use for the combat Marine in varied and extreme situations. As such, ability to operate in all climates, limited ration preparation time, volume/weight minimization, etc., have been important design considerations. The result is a preferred ration system concept that is responsive to the needs of the MAGTF Commander and the individual combat Marine in the initial phases of an amphibious assault. New and/or improved technologies will be required actually to produce the ration at some future point. Of particular significance are the development of specific intermediate-moisture food products offering high mass (caloric) density, exacting "true to form" flavors, and phase change resistance down to 0°F. Low volume packaging techniques should be explored in addition to exothermic ration heating applications. Information regarding complex human factors interactions between such variables as ration quality, component variety and menu variety needs to be further expanded.

This "front-end analysis" approach to ration design has outlined prospective operational situations and ration design options and, in some areas has raised more questions than answers. Nevertheless, both the customer and the developers now have, at a minimum, a plan from which to move forward and jointly make decisions regarding the ration's final design.

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## APPENDIX A.

Rich Product Corporation: What is Freeze Flo®?

Freeze Flo® is a registered trade name of Rich Products Corporation. Citation of trade names does not constitute an official endorsement or approval of the use of such items.

Note: Rich Products Corporation is the source of all information in Appendix A.

Rich's®

RICH PRODUCTS CORPORATION

INTRODUCES

FREEZEFLO®

Rich's®

## WHAT IS FREEZE FLO® ?

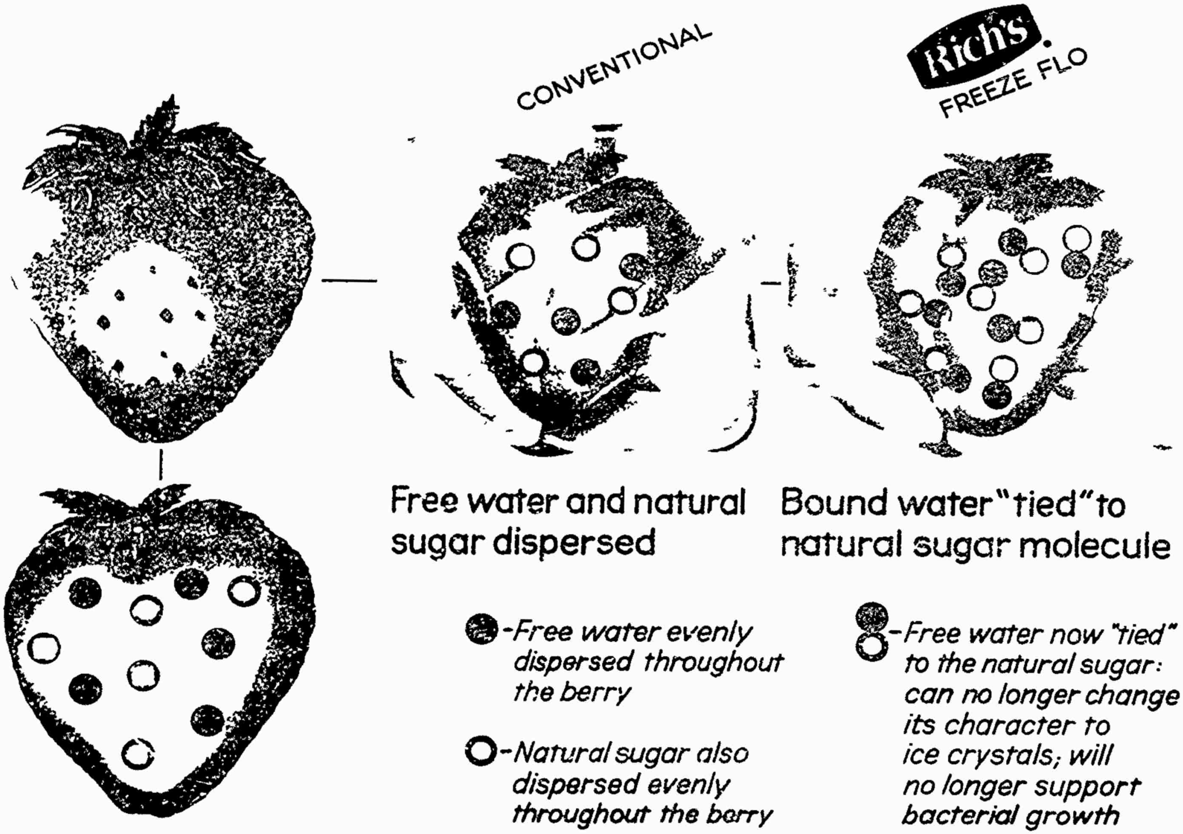
- Freeze Flo is a revolutionary new patented process developed by Rich Products over a seven-year period at an investment of over 2½ million dollars.

- Freeze Flo is a natural process which isolates and controls the moisture content in a product. The "free water" or moisture, becomes so tightly bound to other natural substances, e.g., Protein, Sugar, Salt, or Unsaturated Vegetable Oils, that it is no longer free to form ice crystals, or freeze solid.

- This process, therefore, enables a product to be frozen without crystallizing or hardening. It keeps products soft at zero degrees Fahrenheit and lower, and eliminates the need to thaw frozen products before use.

- Freeze Flo, through the binding of the "free water", also eliminates an environment for bacterial growth, thereby, making the product microbiologically stable.

# Dynamics of the Freeze Flo® Process



# Bacterial Plate Count In Eclair Filling

40° Fahrenheit (Refrigerated Temperature)

| DAYS: | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **Conventional** Chocolate Eclair | 500 | [illegible] | 500,000 | 5 Million | [illegible] | TNC* |
| Rich's **Freeze Flo**® Chocolate Eclair | 10** | 10** | 10** | 10** | 10** | 10** |

At Normal Room Temperature

| DAYS: | 1 | 2 | 3 |
|---|---|---|---|
| **Conventional** Chocolate Eclair | [illegible] | 1 Billion | TNC* |
| Rich's **Freeze Flo** Chocolate Eclair | 10** | 10** | 10** |

*TNC-too numerous to count

**10 or less

Rich's®

## ENERGY SAVING BENEFITS OF FREEZE FLO®

Example: A product weighing two pounds (or 908 grams) with one pound (454 grams) of water. (figures approximate)

. To lower temperature from 40°F. (4°C.) to 0°F. (-18°C.):

| | Temperature: | | Non Freeze Flo Product | | Freeze Flo Product | |
|---|---|---|---|---|---|---|
| | F° | C° | BTU's | Gram Calories | BTU's | Gram Calories |
| | 40° – 32° | 4° – 0° | 4 | 1,008 | 4 | 1,008 |
| Latent Heat Zone | 31° | -1° | 144 | 36,288 | -0- | -0- |
| | 31° – 0° | -1° – -18° | 16 | 4,032 | 16 | 4,032 |
| | TOTALS: | | 164 | 41,328 | 20 | 5,040 |

1 BTU = 252 gram calories

Savings of 88%!

Rich's®

<u>SUMMARY: WHY FREEZE FLO®?</u>

- Freeze Flo offers a number of significant advantages:

  1) Products can be converted to Freeze Flo that are kept at <u>room temperature</u>, <u>refrigerated or frozen temperatures</u>!

  2) Freeze Flo products are microbiologically stable and do not permit bacterial growth!

  3) The shelf-life of Freeze Flo products, at room, refrigerated, or frozen temperatures is greatly extended!

  4) Tremendous savings in energy are available to frozen food manufacturers by avoiding the "latent heat zone" in the normal freezing process!

  5) New product concepts, never before possible, are now conceivable!

  6) Frozen foods now may be consumed or used <u>immediately</u> from the freezer ($0^{o}F$ or $-18^{o}C$).

Rich's®

7) Savings in less spoilage and lower labor costs are possible!

- Companies who, through licensing agreements, market products using the Freeze Flo technology will have significant and advertisable claims over competition!

- At a press conference in New York City on June 24, 1980, Freeze Flo was officially introduced world-wide, to the television, radio, newspaper and magazine media, and wire services, e.g., AP and UPI.

- Copies of some of the articles and of the advertisements used on Freeze Flo are included in the back of this booklet.

Rich's®

FREEZE FLO® PRODUCTS MARKETED BY RICH'S

Chocolate Eclairs

Filled Donuts

Bettercreme™ Filling & Icing

Rich's

## OTHER FREEZE FLO® PRODUCTS

| | | |
|---|---|---|
| Beverages | - | Orange Juice Drink Concentrate, Iced Tea Concentrate, Fruit Punch Concentrate, etc. |
| Batters | - | Pancake Batter and Cake Batter |
| Fruits | - | Apples, Strawberries, Cherries, Blueberries, etc. |
| Desserts | - | Fruit Pies |
| Sauces | - | Tartar Sauce, Seafood Cocktail Sauce |
| Egg Yolks | - | Sugared Egg Yolks |

Rich's®

<u>SOME OTHER PRODUCTS APPLICABLE TO THE FREEZE FLO PROCESS</u>:

- Frozen Donut Batters, Pie Batters
- Frozen Puddings
- Shelf-Stable Fillings & Cakes
- Frozen Sauces and Dressings
- Frozen Soup Concentrates
- Frozen Meats (Processed and Prepared)
- Frozen Cakes and Other Bakery Products
- Frozen Non-Dairy Creamer
- Frozen Non-Dairy Shake
- Frozen Milk Mate Concentrate
- Ice Cream

These products and others are being further researched and tested to refine various characteristics such as texture, taste, flavor, consistency, etc.

Rich's®

## FREEZE FLO® IN THE FUTURE

- Rich's is continuing to discover new products almost every day where the Freeze Flo technology has application.
- United States and internationally known corporations, as well as Rich Products will be producing a wide variety of products using this innovative breakthrough.
- Licensing agreements, world-wide, will provide the opportunity for the Freeze Flo technology to be incorporated into foods that are refrigerated, frozen, or ambient, giving them longer product-life, and bacterial stability, as well as convenience never before possible.

APPENDIX B.

Intermediate Moisture Foods - A Brief Review

TABLE OF CONTENTS

# I. INTRODUCTION

Intermediate moisture foods (IMF) are semimoist, shelf stable foods with water contents between 20% and 40%,[1] and water activities (Aw) in the 0.65 to 0.85 range.[2] These foods are characterized by their ability to be eaten as is (no preparation required) without giving a sensation of dryness in the mouth. They are plastic (flexible) in nature and can therefore be molded into cohesive bars. IMF are shelf stable even though viable microorganisms and spores may be present. The stability of these foods is due to the reduction of available water through the addition of water binding substances (humectants) such as salt, sugar, and glycerol. As a result of their microbiological stability, the safety of IMF is not principally dependent on their packaging.

IMF can be broken down into two categories, traditional and nontraditional (fabricated) foods. Traditional IMF include jams, jellies, confectionaries, certain cheeses, jerky, some types of sausage, pemmican, country cured hams, dried fruits, and some bakery items. Nontraditional or fabricated IMF include semimoist pet foods and those specialized items designed for military use. These specialized items include canned prefried bacon, canned bread and meat, vegetables, fruits, and casserole items developed by or for the U.S. Army Natick Research, Development and Engineering Center (NRDEC). Table B-1 gives a listing of IMF available in the market.[3]

The general principle of food preservation through controlled moisture has been used by man for many centuries. Drying or salting to preserve meat is one of the earliest known methods of food preservation. Technical research in the area of IMF began in earnest in the early 1960's when researchers began to examine the relationship between water activity and food stability. NRDEC became involved in developing innovative IMF in the late 1960's as a form of preservation for ration components.

TABLE B-1. IMF Products Noted on Supermarket Tour.

| | Name | Manufacturer |
|---|---|---|
| Historical | | |
| | Jams and Jellies | |
| | Sausage | |
| | Some cheese | |
| | Dried Fruit | |
| | Marshmallows | Many |
| | Honey | |
| | Country Hams | |
| | Jerky | |
| | Salted Fish | |
| | Maple Syrup | |
| Traditional | | |
| | Pop-Tarts | Kelloggs® |
| | Slim Jims | General Mills® |
| | Hostess Pies | ITT Continental® |
| | Ready-to-Spread Frosting | General Mills® |
| Semitraditional | | |
| | Breakfast Squares | General Mills® |
| | Pie Sticks | General Mills® |
| | Pizza Crust | Fairmont Foods® |
| Novel | | |
| | Pet Foods | |
| | Infusion Cooked | |
| | Extrusion Particles | Many |
| | Extrusion Patties | |

## II. COMPARATIVE ADVANTAGES OF INTERMEDIATE MOISTURE FOODS

The suitability of using IMF in new ration systems can best be determined by comparing the unique properties of IMF items to existing ration components. Current ration alternatives include the full moisture foods principally found in the Meal, Ready-to-Eat (MRE), the freeze-dried compressed items predominantly found in the Food Packet, Assault, and the Food Packet Long Range Patrol (LRP).

IMF offer a buffered approach to food preservation between the extremes of freeze-dried, compressed products and wet products. These foods maximize a number of the advantages of both wet and dry systems for military ration use. IMF are generally of reduced weight and volume in comparison to their full moisture counterparts. However, they can be heavier and bulkier than a comparative dehydrated, compressed item.

The advantages for military use are: (1) IMF are concentrated and the decreased weight* over comparable full moisture foods make them relatively calorie dense, which is important for transportation and storage, both on a large scale and on a personal basis (i.e., the individual Marine); (2) IMF are flexible, allowing them to be molded into desired shapes for packaging, transportation and storage; (3) IMF require no preparation, which is particularly important in field situations where meal times may be both spontaneous and rushed; (4) IMF lack the harsh dryness of dehydrated foods and are therefore more conducive to being eaten as is; and (5) IMF are generally more microbiologically stable than alternative food forms, thus lessening packaging requirements.

*The IMF studies reviewed did not include volume data, therefore, comparisons to existing ration components had to be made on a weight-only basis.

## III. NRDEC RESEARCH

### Background

NRDEC first became involved in the development of specialized IMF for the military during the mid 1960's. Their interest was based on a desire to use IMF in space and field ration feeding. The work centered on the development of casseroles, meat, fruit and vegetable items not commonly classified as IMF.

When NRDEC began investigating the possibility of using IMF as primary ration components, few suitable foods could be found. Most items were very high in salt or sugar (such as pepperoni and confectionaries) and therefore not suitable. NRDEC then set out to develop new IMF meat, fruit, vegetable and combination items. The problem was how to combine commonly used humectants (water binding substances--salt, sugar, glycerol) to produce a product that would be both safe and palatable. Several contracts were initiated to research the possibilities.

### Contracts: General Foods and Swift & Company[4,5,6]

Under NRDEC contracts both General Foods and Swift & Company developed IMF items suitable for ration use, including a number of casseroles. Their objectives were to produce foods in the intermediate moisture range that were palatable, nutritionally sound, and having a suitable shelf life for military use. The range of water activities studied was 0.70 to 0.86 and FDA-approved additives were used to control detrimental chemical reactions and microbiological spoilage. The contractors collectively evaluated a number of infusion techniques, infusion solutions, cooking methods, and drying methods. They used the methods found to be most effective when conducting storage studies and subsequent evaluations. The best method was often found to be dependent on the product involved. Evaluation consisted of storage tests for 3 to 4 months at 38°C. Analysis in all cases included tests for moisture content, water activity, microbiology, and panel acceptance. In some instances, further investigations were made including rehydration tests and nutritional analysis (vitamin content).

Both contractors utilized a variety of infusion techniques to incorporate glycerol (and other additives) and bring the food items into the desired Aw range. General Foods found the wet infusion method (soaking and/or cooking the food in a prescribed solution until equilibrium was met) was most desirable since it was an effective and economical method. Swift & Company used a combination of drying and infusion. They found either infusion by soaking in an equilibrium solution or direct addition to the product during formulation was effective. Of the drying methods evaluated, vacuum drying was most effective. Both contractors found their products to be microbiologically safe after the storage period was concluded. Panel evaluations found the products to be acceptable but in some cases acceptability was borderline. General Foods found all their items acceptable, however it was felt improvements, particularly in flavor, still needed to be made. Swift & Company found panel evaluation results to be below the desired level. Problems were found in either flavor or texture depending on the internal solution of the product. (Flavor problems occurred in food of high internal solution, texture problems in those of low internal solution).

The nutritional analysis made under the General Foods contract showed that the changes in vitamin content of the experimental IMF items were comparable to those of traditionally preserved (in this case thermally processed) foods similarly stored.

The recommendations set forth by General Foods and Swift & Company were as follows:

(1) find a bland substitute for glycerol;

(2) initiate research to investigate the role water plays in a food system, including its structure and binding ability;

(3) develop a tenderizing method for internal solutions lower than 50%; and

(4) investigate a product's inherent ability to decrease Aw by chemical and physical means.

NRDEC In-House Investigations

Two studies were made by NRDEC to investigate further the potential use of IMF for the military. Both studies tested the effect of storage on IMF. The first involved a relatively short-term, high temperature storage and the second a long-term, varied temperature storage.

In the first study, four intermediate moisture meat entrees were developed and were placed in storage at 38°C for 6 months.[7] The items (Pork with Barbecue Sauce, Pork with Sweet and Sour Sauce, Pork with Oriental Sauce and Ham with Sweet Mustard Sauce) were made similar to those in the General Foods and Swift & Company studies. The meat was brought to the required water activity (0.81 to 0.86) by cooking in an infusion solution comprised of water, glycerol, salt, potassium sorbate, and flavorings. The sauces were formulated with sufficient glycerol to depress the Aw to the desired level. No antimycotic was required in the sauces since their natural ingredients (high in sugar) were enough to ensure stability.

The cooked meats were combined with their respective sauces, initial tests were made (Aw, microbiological, nutritional, and sensory analysis), and the products were placed in storage at 38°C for 6 months.

The results of the storage test were similar to previous studies. All four items were microbiologically safe over the 6-month period. The nutritional data obtained were comparable to those found in similar testing of existing combat rations. Gross physical examination showed only color changes in the meat components.

The sensory evaluation involved testing at 0, 3, and 6 months by a 29-member untrained panel using a 1-9 hedonic scale (where 1=dislike extremely and 9=like extremely); no standards or controls were used. Panel rating decreased between 0 and 6 months for all four products. However, there was no significant difference between the means at 0 and 6 months for the Pork with Oriental Sauce and the Ham with Sweet Mustard Sauce. The differences for the other two items were highly significant ($p < 0.01$).

The second NRDEC study was similar.[8] Five IMF entree items were developed using the same techniques as the first study. However, the storage tests differed in that the products were stored at three temperatures (4°, 21°, and 38°C) for 12 rather than 6 months.

The results showed that all five items were microbiologically safe at all three temperatures over the 12-month period, and the vitamin losses were similar to those losses occuring in foods prepared by commercial methods and comparably stored. Sensory evaluations indicated that the five products were able to maintain their sensory properties for the full 12 months at 4° and 21° C, however a decline in palatability was detected in the samples after 3 months at 38°C.

Summary

In conclusion, the investigations performed by or for NRDEC in the late 60's early 70's have shown that there is a potential for using IMF as the basis of a military ration. The processing method found best suitable was to control water activity through the addition of humectants. Two methods of incorporating humectants were sucessfully investigated (dry and wet infusion). It was found that the wet infusion method (incorporating additives into a full moisture food) was the most economical. All studies concluded that the products were shelf stable over the given time period (3 to 6 months at 38°C/100°F), they were nutritionally equivalent to their full moisture counterparts, and their major problem was flavor. The need for a new humectant, or the modification of an existing one, is required to provide an effective means of adjusting the Aw safely while not adversely affecting the acceptability of the food.

## IV. CURRENT RESEARCH

NRDEC is currently involved in the development of intermediate moisture cakes for use in the new Army Combat Field Feeding System. These cakes are formulated to produce stability through lowered water activities. Their formulations include high sugar contents as well as the addition of glycerol, propylene glycol, and/or potassium sorbate. The cake batter is simply poured into half-size steamtable pans (Tray Packs) and baked. After filtered air cooling, the pans are hermetically sealed. These cakes can then be stored and transported to the battlefield without refrigeration. Each pan provides 20 servings. Initial storage studies indicate that these Tray Pack intermediate moisture cakes can be held at least 2 years at ambient temperature.

In general, most recent research in the area of IMF foods is centered on related topics rather than actual product development. Investigations in the areas of water activity and humectants continue. Labuza forecasts that the future of IMF lies in the knowledge and utilization of water activity rather than the development of new humectants.[9] However, other researchers disagree and pursue the possibility of alternative humectants.[10-13] Lactic acid is currently under investigation as a potential humectant since it is half as sweet as sucrose (up to 15% concentration by weight). However, its effectiveness is controversial since it appears to be too dependent on the components of the food system.[3] Other hydroxyacids and sodium salts have also been considered for their ability to lower Aw.[12] Research in related areas, such as the development of antioxidants and antimycotics and an increased understanding of the role water plays in a food system, continues and will be useful for future investigations in the production of IMF.

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NRDEC In-House Investigations

Two studies were made by NRDEC to futher investigate the potential use of IMF for the military. Both studies tested the effect of storage on IMF. The first involved a relatively short-term, high temperature storage and the second a long-term, varied temperature storage.

In the first study, four intermediate moisture meat entrees were developed and placed in storage at 38°C for 6 months.[7] The items (Pork with Barbecue Sauce, Pork with Sweet and Sour Sauce, Pork with Oriental Sauce and Ham with Sweet Mustard Sauce) were made similar to those in the General Foods and Swift & Company studies. The meat was brought to the required water activity (0.81 to 0.86) by cooking in the infusion solution comprised of water, glycerol, salt, potassium sorbate, and flavorings. The sauces were formulated with sufficient glycerol to depress the Aw to the desired level. No antimycotic was required in the sauces since their natural ingredients (high in sugar) were enough to ensure stability.

The cooked meats were combined with their respective sauces, initial tests were made (Aw, microbiological, nutritional, and sensory analysis), and the products were placed in storage at 38°C for 6 months.

The results of the storage test were similar to previous studies. All four items were microbiologically safe over the 6-month period. The nutritional data obtained were comparable to those found in similar testing of existing combat rations. Gross physical examination showed only color changes in the meat components.

The sensory evaluation involved testing at 0, 3, and 6 months by a 29-member untrained panel using a 1-9 hedonic scale (where 1=dislike extremely and 9=like extremely); no standards or controls were used. Panel rating decreased between 0 and 6 months for all four products. However, there was no significant difference between the means at 0 and 6 months for the Pork with Oriental Sauce and the Ham with Sweet Mustard Sauce. The differences for the other two items were highly significant ($p < 0.01$).

The second NRDEC study[8] was similar. Five IMF entree items were developed using the same techniques as the first study. However, the storage tests differed in that the products were stored at three temperatures (4°, 21°, and 38°C) for 12 rather than 6 months.

The results showed that all five items were microbiologically safe at all three temperatures over the 12-month period, and the vitamin losses were similar to those losses occuring in foods prepared by commercial methods and comparably stored. Sensory evaluations indicated that the five products were able to maintain their sensory properties for the full 12 months at 4°C and 21°C, however, a decline in palatability was detected in the samples after 3 months at 38°C.

Summary

In conclusion, the investigations performed by or for NRDEC in the late 60's early 70's have shown that there is a potential for using IMF as the basis of a military ration. The processing method found best suited was to control water activity through the addition of humectants (water binding substances). Two methods of incorporating humectants were sucessfully investigated (dry and wet infusion). It was found that the wet infusion method (incorporating additives into a full moisture food) was the most economical. All studies concluded that the products were shelf stable over the given time period (3 to 6 months at 38°C/100°F), they were nutritionally equivalent to their full moisture counterparts, and their major problem was flavor. The need for a new humectant, or the modification of an existing one, is required to provide for an effective means of adjusting the Aw safely while not adveresly affecting the acceptability of the food.

NRDEC is currently involved in the development of intermediate moisture cakes for use in the new Army Combat Field Feeding System. These cakes are formulated to produce stability through lowered water activities. Their formulations include high sugar contents as well as the addition of glycerol, propylene glycol and/or potassium sorbate. The cake batter is simply poured into half-size steamtable pans (Tray Packs) and baked. After filtered air cooling, the pans are hermetically sealed. These cakes can then be stored and transported to the battlefield without refrigeration. Each pan provides 20 servings. Initial storage studies indicate that these Tray Pack intermediate moisture cakes can be held at least 2 years at ambient temperature.

In general, most recent research in the area of IMF is confined to related aspects rather than product development. Investigations in the areas of water activity and humectants continue. Labuza forecasts that the future of IMF lies in the knowledge and utilization of water activity rather than the developement of new humectants.[9] However, other researchers disagree and pursue the possibility of alternative humectants.[10-13] Lactic acid is currently under investigation as a potential humectant since it is half as sweet as sucrose (up to 15%

concentration by weight). However, its effectiveness is controversial since it appears to be too dependent on the components of the food system.[3] Other hydoxyacids and sodium salts have also been considered for their ability to lower Aw.[12] Research in related areas, such as the development of antioxidants and antimycotics and an increased understanding of the role water plays in a food system, will be useful for future investigations in the production of IMF.

## V. SUMMARY AND CONCLUSIONS

IMF are semimoist, ready to eat, shelf stable, contain between 20% and 40% moisture, and have water activities in the 0.65 to 0.85 range. Traditional IMF include jams, jellies, some cheeses and sausages, confectionaries, and certain bakery items. Nontraditional or fabricated IMF include semimoist pet foods and the prototype items developed by or for NRDEC.

In developing an IMF a number of considerations must be made including: (1) the nature of the food--both the condition it is in before processing and the susceptability of its components to degradative reactions (chemical and microbiological); (2) the influence of additives on both the food and on each other; (3) the physical conditions to which the food will be subjected; and (4) the method used to achieve reduced water activity.

Several areas require exploration in regard to the future development of IMF. These areas include are: (1) looking for alternative humectants that are both safe and effective (especially any that may be inherent to the products); (2) finding ways to increase the amount of existing humctants without detrimental effects; (3) establishing methods to control Aw at lower concentrations of additives; and (4) investigating further the role water plays in food preservation.

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APPENDIX C.

Ralston Purina® (Exothermic) Patent and US Army Natick RD&E Center Evaluation Comments

1

3,578,459
FOOD PRODUCT

James E. Corbin, Webster Groves, Mo., assignor to The Ralston Purina Company, St. Louis, Mo.

No Drawing. Filed July 18, 1968, Ser. No. 745,682
Int. Cl. A23l 1/10
U.S. Cl. 99—1 16 Claims

## ABSTRACT OF THE DISCLOSURE

The method of producing a novel food product comprising coating the surfaces of a substantially dry food product with an edible, chemically reactive composition which, when contacted with an aqueous liquid, forms an exothermic reaction, thereby producing a resulting heated food product.

## BACKGROUND OF THE INVENTION

This invention relates to food products and, more particularly, to foods which result in the production of heated food products.

The art is familiar with food products, particularly, pet foods or cereals which are currently available to the consumer. These products include the dry cereal-type which may be consumed in the dry form or may be mixed together with liquids such as water or milk products to make a more palatable mixture. However, all of the products currently available are of the "cold" type, i.e., any heat that may be imparted to any food product must be applied from an external source. Since it is generally known that warm or heated type food products are more attractive and palatable for human or animal consumption, it would be highly desirable to provide a method for producing such products to provide the consumer with a product that would be easy to use and not require the application of an external heat source to obtain a warm or heated palatable food product.

## SUMMARY OF THE INVENTION

In accordance with the present invention, a novel food product is accomplished in a method which comprises contacting and substantially coating the surfaces of a dry, food product with an edible, chemically reactive composition, said composition forming an exothermic reaction when contacted with an aqueous liquid and thereby forming a resulting heated food product.

The particular coating composition placed on the surfaces of the dry food product reacts with the aqueous liquid to form an exothermic reaction which in turn provides the heat necessary to raise the temperature of the food product. The aqueous liquid also provides the necessary moisture to soften the dry food product to make it more palatable.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is best accomplished in a method which comprises substantially coating the surfaces of a dry cereal-type food product, e.g., cereals or dog food, with a chemically reactive composition. Such chemically reactive compositions include calcium oxide, phosphorous pentoxide, strontium oxide, barium oxide and the like. The chemically reactive compositions may be present on the food product in a range of from about 0.003% by weight to about 10% by weight based on the total weight of the food product and preferably from about 3% by weight to about 5% by weight. Where calcium compositions are employed, such compositions provide a readily available source of calcium to supplement the mineral diet.

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The chemically reactive composition may be applied to the dry food product in any known manner which would provide for substantially coating the exterior surfaces thereof.

The above coated food product must be contacted with an aqueous liquid in order that the chemically reactive composition may combine with said liquid to form an exothermic reaction and thus produce a resulting heated product. The liquid employed may be any liquid that, when contacted with the chemically reactive composition, would produce an exothermic reaction, e.g. water. However, it has been found that a reaction may be initiated at a more rapid rate by the addition of an edible acid to the water prior to contacting the water with the coated food product. The amount of liquid employed with the coated food product should be in the range from about 20% to about 150% by weight based on the total dry weight of the food product.

The edible acids that may be employed in the liquid portion of the composition include phosphoric acid, hydrochloric acid, citric acid, acetic acid, and the like. In the case of phosphoric acid, it has been found that the phosphorous ions counterbalance, for example, the calcium, where calcium oxide is employed as the chemically reactive composition, to produce a food product having a desirable and nutritious mineral balance. Such acids should be present in an amount from about 0.05% by weight to about 15% by weight based on the total dry weight of the food product and preferably from about 0.5% by weight to about 10% by weight.

The basic dry cereal-type of food product which is employed in the invention may be any of the various, commercially available types of products now available to the consumer. It is essential that the food product be substantially dry since any excessive moisture would cause the chemically reactive coating to react prior to consumption. Moisture should not be present in the food product in an amount in excess of about 10% and preferably about 5% or less.

The coated food product and the aqueous liquid may be mixed in any conventional manner to permit the chemically reactive coating to contact said liquid. Tests show that the particular components employed in producing the food products of the invention result in products having an elevated temperature of from about 80° F. to about 120° F. as compared to a room temperature of, for example, 75° F.

The particular method of preparation and resulting product of the invention provides a means of providing a heated food product without the necessity of applying an external heat source. The products of the invention may be packaged, for example, in a moisture-impermeable two-compartment plastic bag having a breakable diaphragm positioned between the compartments with the substantially dry coated product in one compartment and the liquid in the other. The consumer need only break the diaphragm to cause the liquid to combine with dry, coated product to obtain the heated product of the invention.

The following examples are illustrative of the invention and are not intended to limit the scope thereof.

### EXAMPLE 1

One hundred fifty grams of a commercially available dry cereal-type dog food were mixed together with 4 grams of calcium oxide. Mixing was conducted until substantially all surfaces of the dog food was coated with a thin layer of the calcium oxide. In a seperate container, 4.0 mls. of phosphoric acid were added to 100 mls. of water and the resulting mixture was mixed together with the calcium oxide-coated dry dog food. The temperature of the coated dog food was about 75° F. prior to the addition of the acid-water liquid. After mixing, the exothermic reaction between the calcium oxide coated dog food and the acid-water liquid caused the temperature of the dog food to rise to a temperature of about 94.5 F., a rise in temperature of nearly 20° F.

A test was conducted to determine the degree of preference of the heated product over a product at room temperature. Ten dogs were each given two feeding pans containing their feed. One pan contained a dog food prepared by adding about 100 mls. of water (about 75° F.) to 100 gms. of a dry cereal-type food product. The other pan contained the heated product made in accordance with the procedure of Example 1. Several pounds of each type of feed were prepared for the test.

The test results show that all ten dogs ate from both pans consuming about 18 pounds of the non-heated product with one dog preferring the non-heated product. However, the same ten dogs consumed about 38 pounds of the product of the invention with nine dogs preferring the heated product.

EXAMPLE 2

The procedure of Example 1 is substantially repeated except that water only is employed as the liquid. The temperature of the dog food was raised about 15° F. The resulting product is substantially the same as that produced in accordance with Example 1.

EXAMPLE 3

The procedure of Example 1 is substantially repeated except that dry pre-cooked oatmeal is substituted for the dog food. The resulting product has a rise in temperature substantially the same as that produced in accordance with Example 1.

EXAMPLE 4

The procedure of Example 2 is substantially repeated except that dry pre-cooked oatmeal is substituted for the dog food. The resulting product has a rise in temperature substantially the same as that produced in accordance with Example 2.

In place of the particular chemical composition and aqueous liquids employed in the examples, other compositions and aqueous liquids may be employed as hereinbefore described to obtain substantially the same results.

I claim:

1. A method for producing a novel food product which comprises contacting and substantially coating the surfaces of a dry food product with an edible chemically reactive composition and contacting said coated product with an aqueous liquid, said chemically reactive composition being capable of exothermically reacting with said aqueous liquid upon contact therewith to produce a resulting heated food product.

2. The method according to claim 1 wherein the chemically reactive composition is calcium oxide.

3. The method according to claim 1 wherein the chemically reactive composition is present in an amount from about .003% to about 10% by weight.



4. The method according to claim 1 wherein the aqueous liquid is water.

5. The method according to claim 1 wherein the aqueous liquid is a mixture of water containing a minor amount of an edible acid.

6. The method according to claim 5 wherein the edible acid is present in an amount from about .05% to about 15% by weight.

7. The method according to claim 5 wherein the edible acid is phosphoric acid.

8. The method according to claim 1 wherein the dry food product contains 10% or less of food moisture.

9. A novel food product capable of producing an exothermic reaction when contacted with an aqueous liquid to form a resulting heated food product which comprises a dry food product having contacted on the surfaces thereof an edible chemically reactive composition capable of exothermically reacting with said liquid.

10. The product according to claim 9 wherein the chemically reactive composition is calcium oxide.

11. The product according to claim 9 wherein the chemically reactive composition is present in an amount from about .003% to about 10% by weight.

12. The product according to claim 9 wherein the dry food product contains 10% or less moisture.

13. A novel dry food product capable of producing a rapid exothermic reaction to form a heated food product when contacted with an aqueous liquid which contains an edible acid in an amount from about .05% to about 15% by weight and which has contacted on the surfaces of the product an edible chemically reactive composition capable of rapid exothermic reaction with an aqueous liquid.

14. The product according to claim 13 wherein the chemically reactive composition is calcium oxide.

15. The product according to claim 13 wherein the chemically reactive composition is present in an amount from about .003% to about 10% by weight.

16. The product according to claim 13 wherein the dry food product contains 10% or less moisture.


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FRANK W. LUTTER, Primary Examiner

W. L. MENTLIK, Assistant Examiner

U.S. Cl. X.R.

99—2, 83, 166

## US ARMY NATICK RD&E CENTER EVALUATION OF RALSTON PURINA® 1968 PATENT ON EXOTHERMIC REACTIVE COATINGS

### First Reviewer

The concept is interesting, and patent claims do show that food products can be heated by hydrolysis/neutralization reactions with chemicals coating the foods. The chemicals listed ($CaO$, $P_2O_5$, $SrO$, and $BaO$) are all very strong drying agents that are rapidly hydrolyzed by reacting with water in exothermic reactions. Of these only CaO is approved as a Generally Regarded as Safe (GRAS) food ingredient, but the purpose and concentration of CaO used as a coating may not fall under the GRAS umbrella for this particular use. FDA would have to be consulted for a ruling.

I am personally nervous about this application. Coating with CaO (quicklime) would preclude use of the product as is without adding water. The lime could react with water in the mouth of the consumer and cause discomfort and/or burns. If acid is not added in the hydration step, strongly basic $Ca(OH)_2$ (hydrated lime) will result. Adding phosphoric acid will produce calcium phosphate. Phosphoric acid is GRAS, but I'm not sure if we would want to run the risk of the consumer directly consuming the acid portion, which is greater than 0.5 M with a pH of less than 1.0. Citric acid might be better to use than phosphoric acid.

The patent does address the stability problems and the need to protect such a coated product from moisture to retain its effectiveness; military requirements for long-term stability may be quite difficult to meet. The ideas in lines 52 to 59 about a compartmental packaging might solve some of the stability and safety questions I have. The complex packaging would certainly add to cost, and may be beyond the criterion for use by the 10%-tile troops.

In sum, I find the concept much more appropriate for feeding pets rather than troops. Some person has to prepare the food for the pets, and we know this is not the case for troops. I don't see any simple and safe alternatives for a similar exothermic and edible reactive coating system. Humans may also be more discriminating about the effects of such a coating system on the appearance and taste of the product than the 9 of 10 test subject dogs used by Ralston.

### Second Reviewer

From a nutritional standpoint, the phosphorous content of the invention is high in comparison to the optimum level of phosphorus of 1:2. In this case, it is estimated to be 1½:2. There are differences of opinion as to the effect of high phosphate levels in the human diet. However, animal experiments have clearly established that a high ratio of phosphorus to calcium leads to an accelerating effect on bone resorption. Thus, pronounced bone loss is seen in animals both due to insufficient dietary calcium as well as an excess of dietary phosphorus. While some studies in humans suggest that a wide range of P to Ca ratios from 1:2 to 2:1 can be tolerated, there are other reports of excessive phosphorus leading to major changes in calcium metabolism.

The temperature of the product is raised only about 20°F. It is questionable whether additional calcium oxide and phosphoric acid would raise the temperature substantially. Additionally, it is desirable to add more than 4 g of calcium oxide which in itself represents an increase of over 250% of the daily requirement for calcuim.

The requirement of about 100 ml of water for 150 g of food is excessive from a logistic standpoint. Phosphoric acid is syrupy liquid and cannot be transported as such. The temperature of the water used for mixing will also affect the final temperature. Water alone can be used without the acid, but the water temperature is a factor to be considered.

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Names of reviewers are available upon request to Paul Short, Advanced Systems Concept Directorate, U.S. Army Natick Research, Development and Engineering Center, Natick, MA 01760-5015.

# APPENDIX D.

## Nutritional Considerations for Assault Marines

TABLE OF CONTENTS

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## I. WATER

### Overview

Water is the major component of the human body, accounting for approximately 60% of its makeup in the average young adult male.[1] It provides the necessary medium for most cellular activities as well as acting as a transportation system, carrying nutrients to the cells and eliminating wastes.

The average adult requires approximately 2½ liters of water a day for temperate and cold environments. In hot environments this requirement greatly increases. A sedentary soldier in very hot weather may require 7-11 liters a day, however, with exercise this requirement can increase to 19 liters or more. Generally, 54% of the daily intake of water is provided through drinking, 37% from solid food, and the remaining 9% from internal metabolism.[1]

Adequate water intake is essential to the soldier since dehydration results in an intolerance to heat and exercise. In cold environments water intake is important to prevent salt accumulation and it is necessary in hot climates to prevent heat-related illness, such as heat stress, heat exhaustion, and heat stroke. Military history has shown the incapacitating effects of heat exhaustion as a direct result of inadequate water intake.[2] Providing sufficient water is not always a solution since thirst is an ineffective indicator of the body's need for water. It has been found in some instances that command drinking is required to ensure that troops take in an adequate amount of water. Water therefore becomes a medical issue since direct control is required.

Water is the limiting factor for performance from a nutritional viewpoint since symptoms of deficiency appear in a matter of hours where food takes days. The Recommended Dietary Allowances (RDA) for water under ordinary circumstances is 1 ml/kcal for adults.[3] However, it states that "Special attention must be given to the water needs of those consuming high protein diets and of all persons in hot environments."[4] The Military Recommended Daily Allowances (MRDA) (AR 40-25) states that water intake is dependent on caloric intake, climate, and activity and it recommends providing cool water, not electrolyte or sugar solutions, when consuming a normal diet.[5]

### Performance Implications

When water is lost from the body by any means (diuresis, sweat, or vomiting) and is not adequately replaced the loss causes a reduction in blood volume. Decreased blood volume has a twofold effect: (1) it lessens the body's ability to get oxygen to the muscles resulting in fatigue; and (2) it lessens the body's ability to cool itself. These two factors are interrelated since with increased temperature and (physical) activity the body needs to cool itself. With the blood traveling to the skin to release body heat, less blood travels to the muscles. Consequently, less oxygen is supplied, resulting in a decrease in endurance. This results in heat exhaustion and is noted by symptoms of abdominal cramps, nausea, vomiting, increased body temperature, increased pulse, loss of appetite, fatigue, and apathy. Any one of these symptoms would be detrimental to the soldier in combat.

Replacing water as it is used is very important to the soldier since symptoms can occur in a matter of hours and with relatively small losses. A loss of greater than 2% of an individual's body weight can result in symptoms of heat exhaustion.[6]

Physiology

Water requirements are very individualistic and, as stated previously, depend on diet, climate, and activity--all of which are interrelated.

Diet is important for a number of reasons. First, the requirement for water is directly related to the number of calories consumed (1 ml/kcal). Secondly, the ratio of fat, carbohydrates, and protein is important. Carbohydrates have been found to be beneficial in retaining water (and salt).[7,8] Protein, on the other hand, tends to be water dependent. A high protein meal can stress the heat dissipating mechanism by as much as 5%.[9] Sodium intake influences water requirements since it must be properly diluted to be effective. In its extremes, climate influences water needs. In cold environments water requirements should be increased to correspond to increased energy expenditures (i.e., those necessary to perform under harsh conditions--weight of excessive clothing, efforts to move in heavy snows, etc.). Water prevents salt accumulation and compensates for diuresis (often brought on by the cold). Since very low temperatures have been known to dull the thirst mechanism, intake should not be regulated by thirst.

In very hot environments water intake must be increased to compensate for sweat losses. Sweat cools the body and is critical in the prevention of heat exhaustion. In very hot temperatures a physically active person can lose 1½ liters of sweat an hour. This means that in as little as 3 hours a person may lose 6% of his body weight through sweat loss.[2] This loss is critical since it has been shown that if water is not replaced a decrease in work performance will appear at losses greater than 2%.[6,10]

Acclimatization to heat will help the soldier to dehydrate less quickly, but it does not decrease his need for water. In some cases acclimatization has actually increased the body's water requirements.[2,11] An acclimatized soldier may benefit by a reduced loss of ions (Na,K,Cl) since tests have shown these people to have dilute sweat more.[12] Some researchers feel that physical training rather than heat acclimatization is of prime importance.[13] Physical training can cause an increased sweating rate.[14] This increases the water requirement but also increases the body's ability to cool itself, protecting against heat exhaustion.

Activity is important since increased activity increases sweat losses. Both of these, as previously stated, increase the body's need for water.

Additional Considerations

Of chief importance in a discussion of water requirements is to emphasize that man can not train the body to require less water. Water intake is essential to maintain the performance of a soldier in the field. The only action that can be taken is to provide adequate palatable water and to see that it is consumed by whatever means necessary. In some cases command drinking may be required. Educating soldiers on the importance of drinking water should improve self-motivation and discipline.

It has been shown that providing cool verses warm water results in less voluntary dehydration.[2] Also, flavoring heavily chlorinated water may be beneficial.

Prehydration may be advantageous for long term exercises. Researchers found that athletes could continue longer before exhaustion set in by superhydrating with saline solutions.[10]

In cases of severe deficiency recovery may take more than 8 hours--time that may not be available to the soldier in combat.[6]

The sweating rate is decreased only after a severe water deficit and the rate of decrease then is only about 10%.[6] "A well hydrated man sweats only slightly more... than he does when severely dehydrated."[15]

Conclusions

Regulation of water intake should be treated as a medical issue since: (1) requirements vary according to climate, diet, and activity; (2) thirst is not an adequate indicator of need; and (3) disabling deficiency symptoms may appear in a few hours.

Cool, palatable water should be provided in sufficient quantities and at regular intervals (20-30 minute intervals preferred in hot climates).

Education of troops on the importance of drinking water should be provided to improve field discipline and decrease the need for command drinking.

## II. CARBOHYDRATES

### Overview

Carbohydrates (CHO) makes up about one half the daily caloric intake and provide most of the energy in the average diet. CHO assists in the maintenance of body temperature, supplies dietary fiber, has a sparing action on dietary and body protein, is needed for complete oxidation of fat for energy, helps maintain activities of the central nervous system (it is the sole energy source for the brain), is necessary for the formation of certain body compounds and tissues, and plays a role in toxin excretion.[1,16]

CHO can be found as starches (complex) in breads, pastas and vegetables, and as mono- and disaccharides (simple) in milk, sugar, honey, and table sugar.

The MRDA has established that 49% (440 gm/3600 cal) of total calories in the operational ration and 100-200 gm in the restricted ration consist of CHO.[5] The USDA recommends 58% CHO, 30% fat, and 12% protein.[3] In fasting, 100 gm to 150 gm are suggested to prevent deamination and conversion of amino acids for energy.

CHOs are broken down into their monosaccharides through a process called hydrolysis. They are then directed to the liver and: (1) released in the bloodstream from utilization of energy or the formation of other compounds; (2) converted to fatty acids and glycerol with subsequent storage as fat; or (3) converted to glycogen and stored in the liver or the muscles.[16] The body only has a very minimal capacity to store glycogen, generally less than one tenth percent of the total body weight.[17]

### Physiology

Several physiological conditions presented below may be of importance to the Marine's performance in combat. These include the following.

1. Prolonged submaximal exercise or repeated bouts of high intensity, short duration exercise (anaerobic--such as the case for the Marine) can only be fueled by CHO.

2. Addition of CHO to a calorie-restricted diet will spare water and electrolyte losses.[18] With the breakdown of 1 gm glycogen, 3 gm water are released and can partially compensate for evaporative water loss.[19,20]

3. Under stress the body quickly and efficiently converts nutrient stores to available forms of energy.[21]

4. Glycogen stores can be manipulated somewhat by consuming more complex CHO 3 to 4 days before an event. This tends to keep energy levels high by filling the glycogen stores.[19,20,22]

5. Repleation of glycogen stores generally takes 12 to 24 hours, in some cases repleation will not be complete until 48 hours.[23]

6. The best CHO sources are those with low glycemic indexes since large amounts of simple sugars (excluding fructose) may cause a surge in the result of insulin and subsequently can cause a hypoglycemic reaction.[16]

7. Hypoglycemic (low blood sugar) can result if blood glucose levels are not maintained. Symptoms include dizziness, fatigue, and hunger.[16]

8. Foods with a low glycemic index provide a steady supply of blood sugar resulting in a lower rate of muscle glycogen depletion.[24] Fructose with an index of 20 has the lowest index (glucose has an index of 100).

9. CHO is 4% to 5% more efficient than fat as energy for working muscles.[18]

10. CHO is digested more rapidly than fats.

11. In the absence of CHO the body will metabolize fat for energy, resulting in the release of ketones into the blood stream.

12. Ketones stress the body's ability to maintain acid/base balances. An abnormal increase, referred to as ketosis, can cause lethargy, dizziness and headaches.

13. Ketonemia and ketonuria (presence of ketones in the urine) can be invariably observed within 3 to 4 days of severe calorie restriction and low CHO intake.[18]

14. Ketonuria appears to suppress hunger.

15. The vitamin B1 (thiamine) requirement increases somewhat with increases in dietary CHO.

16. In cold climates, the body assumes a new level of homeostasis w/adaption, which may result in a shift in metabolism from primary CHO to fat.

Performance Implications

In times of stress, intense physical activity, and lack of sleep, coupled with reduced food consumption, the Marine could experience any number of impairments that could have a detrimental effect on the total mission. These include lethargy, cramps, fatigue, and hunger. Ingestion of at least 100 gm complex CHO per day could reduce some symptoms, as well as spare water and electrolyte losses, body protein, maintain blood levels, and prevent ketonemia.

Conclusions

Research indicates that increased CHO in pre- and postassault diets could fill glycogen stores. In the assault phase when intake is less than normal, increased CHO could reduce several physiological stresses due to reduced caloric intake and thus may significantly impact on the Marine's performance.

As shown in Table D-1, a moderate increase of CHO from 49% to 51% of total calories with a subsequent reduction in the percent of protein calories from 11% to 9% in the operational ration could help provide this added benefit.

TABLE D-1. Present and Preferred Caloric Intakes.

| | PRESENT | PREFERRED |
|---|---|---|
| PROTEIN | 11% | 9% |
| FAT | 40% | 40% |
| CHO | 49% | 51% |

The filling, maintaining, and repletion of stores would need to be considered independently in each assault phase (preassault, assault, and post-assault). Due to the type of activity, level of stress/anxiety, and availability of food, a different nutritional approach needs to be considered for each phase in an effort to optimize the nutritional impact on Marine's performance.

The preassault phase is particularly important because it sets the nutritional stage and can give the Marine an edge. The following outlines the components of each phase.

1. Education.

2. Aerobic endurance training.

3. Preassault exercise. Exercise 3 days before the deployment should be of low intensity. However, it is not advised that no exercise be taken.

4. Garrison menu. Several guidelines established by endurance athletics lead to the following conclusions.

(a) 4 to 5 days before deployment a menu high in CHOs should be offered to build up the body's stores of glycogen--preferably, five or six small meals served uniformly throughout the day.

(b) Day of deployment:

(1) light meals of easily digested CHO;

(2) liquid intake should not be excessive; and

(3) recommend 21 oz approximately 2 hours before deployment and 14-17 oz minutes before. These levels are recommended by the ADA for athletes before an endurance event.

The assault phase is the period the Marine must draw on all his body's reserves, the period where his food choice/selection will have the greatest impact on his performance, and the period CHO is the most critical nutrient. Studies indicate that often Marines in combat do not eat for a period of 1 to 3 days. Appetites increase as combat experience increases but seem to level of at apporximately three-quarters of the usual amount consumed.

In making this limited selection there is no guarantee the Marine will receive the proper nutrients to help sustain peak performance.

During days One to Three, food items should be high CHO food with a low glycemic index, and should contain at least 100 gm CHO. This will maintain energy levels, be water saving, and improve performance by reducing the risk of hypoglycemia (the depletion of muscle glycogen).

The postassault period is important for rebuilding body reserves due to the lag factor of replenishing body stores. Several days of controlled food intake and exercise would be necessary to complete this if there would be repeated episodes of low caloric intake.[25]

## III. PROTEIN

### Overview

Protein is required as a source of amino acids and nitrogen, and for the growth and maintenance of body tissues, regulation of body processes, and production of energy (4 Kcal/gm). Protein also influences the body's water balance. Both the quality and absorption of protein is important. The quality of a protein is related to its essential amino acid content. There are 22 amino acids, 9 of which are referred to as the essential amino acids (those not synthesized by the body) and must be provided in the diet. The remainder can be synthesized in the body. Complete proteins contain the nine essential amino acids whereas incomplete proteins lack one or more. Complete proteins are generally from animal sources and tend to be absorbed better than incomplete proteins, which are generally of plant origin.

Protein requirements are usually determined by the amount necessary to keep the body in a positive nitrogen balance. This balance is dependent on several factors including physiological and psychological state (injury growth, environmental and emotional stresses), body protein reserves (muscle mass), caloric value of the diet, and the amount of amino acids, both essential and nonessential in the diet. Since the body cannot store protein there is a constant need for dietary protein.

The RDA for protein is set at 0.8 gm/kg of body weight (for example, 56 gm/day for a 70 kg male).[3] The average American diet however, provides 1.5 to 2 times this amount. The MRDA is 100 gm/day for men on operational rations and 50-70 gm/day for restricted rations.[5] These figures are approximately double the RDA. AR 40-25 states the high protein requirement was set to "enhance diet acceptability" and to provide a diet more typical to the soldier's ordinary eating habits.[5]

### Physiology

Approximately 23 gm/day of complete protein is required to compensate for "protein turnover"--a term used for the continuous process by which all body proteins, including muscle, are broken down and replaced with new proteins.[25] Additional protein is required to compensate for the less than complete proteins provided in a mixed diet as well as provide for the differences in individual needs.

In times of body building, additional protein would be required but only to a limited extent since protein synthesis occurs at a set rate. The Letterman Army Institute of Research found when increasing protein intake over 100 gm only 7 percent of this protein was retained for building muscle mass.[25,26] Additional intake over this would be either used energy or stored as fat. As an energy source. protein is relatively inefficient. In order to be utilized it must first be converted to a carbohydrate-like compound. Consequently, protein is stored as fat unless other energy sources (carbohydrate or fat) are lacking. This conversion process irreversibly stores protein as fat.

The possible need for increased protein to compensate for losses associated with psychological, physiological, or environmental stress is a topic of much debate. While some researchers feel requirements should be increased to fight stress,[27] it is generally acknowledged that the amount set by the RDA is adequate during times of stress.[9,27,28] Deficiency symptoms (reduced performance, decreased muscle mass) are most likely to occur only after a prolonged, continuous, reduced protein intake.[29] It has been suggested that to prevent deficiencies no less than 5 to 6 percent of calories be provided through protein.[30,31] Protein provides little protection to cold and therefore an adherence to the RDA would provide adequate protein in cold weather environments under normal conditions.[29] In hot climates as well as in cold climates when heavy gear and strenuous exercise cause sweating, an increase in protein intake has been recommended by Consolazio to compensate for nitrogen losses in sweat.[26] Other researchers caution against an excessive intake of protein because this build up may in fact simply increase urine output, thereby increasing water requirements.[25,30,32]

Irwin and Hegsted in a 1971 review [31] on protein requirements suggested that while an increase in protein has been called for in times of stress to compensate for nitrogen losses additional study is needed to determine whether or not an actual increase in protein will compensate for these losses. Also, they state that climatic stresses have not been studied under controlled conditions and that the effect of the quality of protein needs investigation. The Dairy Council Digest suggested that dietary protein not be increased in time of severe stress resulting from injury, operation, trauma, infection or burns since the increase would only increase synthesis of urea and excretion. They say protein should be taken in when it can best be utilized (i.e., recovery period).[33] Whether this belief would apply when the stress was related to precombat tension or environmental extremes was not discussed.

Acclimatization to heat and its effects on nitrogen losses is also a matter of controversy. Researchers differ in opinion as to whether or not an increased loss of nitrogen in sweat is compensated by a decrease in urinary nitrogen output.[9,27,30,34] However, it seems apparent that acclimization would only be beneficial in conserving nitrogen.

Additional Considerations

Excess protein may have a detrimental effect on water economy and can lead to dehydration. Protein not utilized by the body is broken down since the nitrogen must be removed prior to its conversion to energy or storage as fat. Excess nitrogen is converted to urea and passed in the urine placing an increased demand on the body's water needs. In 1959 the Quartermaster Food & Container Institute, in an interim report, recommended a maximum of 7 to 8 percent protein in times when water economy was of prime importance.[35]

Performance Implications

The protein needs of the Marine may best be regulated according to conditions. Prior to deployment the soldier should be in peak physical condition. Left to his own choice he will probably be consuming an adequate protein diet. There is no research to indicate that increased protein intake prior to stress will help alleviate that stress. The body does not store excess protein so it seems apparent that only intakes required to keep the body in peak condition would be necessary. During combat it may be beneficial to limit protein in order to spare water and provide energy calories through the most efficient sources (carbohydrates and fats). However, protein should not be limited to the extent where performance would be sacrificed. It should be noted that after a reduction in protein intake the body may go into a negative nitrogen balance even if intake is adequate. It takes the body a few days to adjust to a reduced intake. A short-term negative nitrogen balance will have no ill effect in most instances. It should be remembered that protein maintains muscle mass and is necessary to build muscles when combined with an adequate muscle building regime. It does not enhance performance. In a combat situation building muscles is not a concern.

Conclusions

1. Protein intake pre- and postoperation is generally no problem due to the large daily intake patterns in the US.

2. There are no conclusive data indicating the benefits of increased protein levels in climate extremes and/or external stressors. Further research is needed to investigate the specific nutrient needs as they relate to the combat Marine.

3. Available research indicates performance would not be compromised if the MRDA protein requirement in the restricted ration was reduced with a corresponding increase in carbohydrates.

4. The protein provided in the ration needs to be of good nutritional quality. Vegetable protein is considered adequate for adults in the view of L. Hambraeus of the Institute of Nutrition, University of Uppsala, Sweden.[36]

5. Nutrition education is important to the Marines' overall understanding of good nutrition and its benefits.

## IV. CHEMICAL/BIOLOGICAL INDUCED BODY STRESSORS

Overview

Stress is defined as a nonspecific response to any demand.[37] "Nonspecific in its causation, stress alters the normal steady state (homeostasis) or challenges the adaptive capacity of the person."[32] Individual response to physical stressors is less individualistic and varies with the degree of stress and nutritional status.

Little information is available concerning emotional and climatic stress-related demands on vitamins, minerals and electrolytes. Several investigators have reported that during moderate to severe stress there is an increase in urinary loss of zinc, copper, magnesium and calcium. Altered blood levels of several nutrients, vitamin A, vitamin C, zinc, and retention of sodium and water have been found to be a result of the metabolic response to stress.[21,33,38,39,40]

Dietary factors in carcinogenesis (physiological) have been given much attention in recent years. It is felt that diet may play a double role as a promoter and as an inhibitor through ingestion of substances that are cancer promoters and certain nutrients (macro and micro) that may act as inhibitors. Research continues in this area.

The Soviets have conducted extensive studies in the area of stressors, (chemical, noise, endurance, biological, etc.) and the role of nutrition in protecting against these stressors. They feel the requirements for vitamins do increase under stress. In fact, diet supplements and adaptogens* are mandated for workers performing certain tasks or working in chemical environments. It is felt that Soviet research lacks adequate biochemical explanation for observations and inadequate experimental reporting, and therefore Western scientists have been slow to recognize their work as a basis for further research.

Conclusions

Research efforts should increase in the area of xenobiotics and, more specifically, the nutritional relationship of the Marine to the particular stressors (emotional, physical, environmental and chemical/biological) encountered in a combat situation.

Because most research indicates that stress can lead to or aggravate nutritional deficiencies, it is necessary to ensure the diets before and after assault are supplying at least the RDA requirements.

*~~A Soviet term referring to~~ any substance or mixture of substances that improves the body's ability to respond or adapt to physical and/or mental stress.

## V. CAFFEINE

### Overview

Caffeine is one of the most commonly used stimulants and one of the most controversial.[41] Caffeine occurs naturally in more than 60 plants and is found is such varied products as chocolate, candy, baked goods, puddings, painkillers, and weight control aids. Coffee is the nation's largest source of caffeine (75%) with tea ranking second.[42,43] Caffeine belongs to the major class of xanthines, as does theophylline and theobromine found in tea and cocoa, respectively; it is these xanthines that act as diuretics. The table below lists the main sources.

TABLE D-2. Beverage Sources of Xanthines.[44]

| | Caffeine (mg) | Theophylline (mg) | Theobromine (mg) |
|---|---|---|---|
| Brewed Coffee | 80-115 | -- | -- |
| Instant Coffee | 65 | -- | -- |
| US Brand Tea | 40 | 1 | 2 |
| Decaffeinated Coffee | 3 | -- | -- |
| Cocoa | 5 | -- | 250 |
| Cola (noncaffeinated) | 15-22.8 | | |

Note: The average American consumes about 200 mg of caffeine a day.

### Physiology

Caffeine is absorbed quickly through the bloodstream and virtually reaches every part of the body within 5 minutes. It reaches peak levels in about 1 hour, and sustains its effect up to 3 hours. Physiological changes that could impact on the Marine's performance include:

(1) constriction of the blood vessels of the central nervous system; and

(2) an increase in free fatty acids, which has been associated with sparing muscle glycogen and thereby enhancing capacity for endurance.[45,46]

### Performance Implications

Given the physical intensity of an amphibious assault, a Marine may be asked to perform at his physical limit. To assist, every available nutritional advantage should be provided if possible. Studies have indicated that 250 mg caffeine ingested 60 minutes prior to work with an additional 250 mg fed at 15-minute intervals over the first 90 minutes increased work productivity (endurance) by 7.4%. The perception of exertion remained unchanged.[46] Caffeine increases the plasma free fatty acids, which seems to spare the rate of glycogen depletion from the liver and skeletal muscle. This sparing of glycogen helps delay exhaustion.

Caffeine is a powerful central nervous system stimulant. Doses of 50-250 mg increase alertness, decrease drowsiness, and lessen fatique, all of which may be of significant value to the Marine standing night duty. Higher doses may produce headache, tremors, nervousness and irritability.[47]

## Additional Considerations

While caffeine in doses of 50-250 mg may provide some beneficial effects to the Marine in combat, there are several other effects warranting careful consideration. These include the following.

Withdrawal. It is well documented that caffeine withdrawal for moderate to heavy users (>250 mg/day) may cause headaches, irritability, inability to work effectively, nervousness, restlessness, and lethargy. The symptoms begin 12 to 16 hours after the last dose with most symptoms disappearing after a period of 36 hours without the drug.[41] This could have implications to a Marine who has had no period of reduced consumption before deployment.

Adaptation. Most evidence indicates that tolerance to caffeine builds with time.[48] To the Marine who is a heavy user and who has not reduce consumption prior to deployment, the packets supplied in his daily ration would not have the same effect they would on a noncoffee drinker.

Diuresis. While there are some contradictory studies, the majority of literature suggest that caffeine acts as a diuretic.[43,48] With the ever-present danger of dehydration, large doses of caffeine before deployment could exacerbate this condition.[18]

Smoking. Cigarette smoking is associated with a decrease in caffeine's half-life.[49] (The time caffeine remains in the body from less than 3 hours in a smoker and up to 7 hours in a nonsmoker).[48] Therefore, the possible effects from caffeine supplied in the ration would vary from person to person.

## Conclusions

Information should be provided to the Marine as to the possible benefits of controlled caffeine use and the risks involved with large doses of caffeine as it relates to his performance/endurance in the assault.

Gradual reduction to three cups (240-300 mg) is desirable among heavy users prior to assault to prevent withdrawal and diuresis once deployed.

# VI. VITAMIN C

## Overview

Vitamin C (ascorbic acid) was the first individual nutrient to be widely associated with disease.[50] However, it was not until 1933 that the antisorbutic factor was identified as vitamin C.[1] Since then, vitamin C has been the subject of much research and has held much public attention.

The Ten State Survey and the First Health Nutrition Examination Survey show that vitamin C is not a major problem among the populations studied.[1] The average U.S. daily intake is about 117 mg.[50] The MRDA and the RDA have established the requirement at 60 mg/day and the restricted ration at 30 mg/day.[3,5] Smokers may have an increased requirement to compensate for the impaired bioavailability of the vitamin.[1]

Vitamin C can not be synthesized by the body, it must be received through food sources, such as citrus fruits, leafy green vegetables, broccoli, cabbage, tomatoes, and potatoes.[1] If a supplement is used, it should be taken with meals to increase iron absorption.[51]

When in the dry crystal form, vitamin C is quite stable. However, when in a water solution it will undergo inactivation when exposed to air, heat, light, or metals (such as copper and iron). Vitamin C is destroyed in the freeze-drying process. It is unstable in an alkali medium and is fairly stable in an acid solution.

The average body pool is 1.5 gm and studies indicate that it cannot be increased further.[52] The clinical deficiency (scurvy) usually occurs when body stores are less than 300 mg.[38,53] Under normal conditions 3 percent is metabolized each day with repletion proportional to intake in about 3 to 5 hours.[3,23] Therefore, it would take 30-45 days before early symptoms of fatigue and poor performance are noticed.

## Physiology

Vitamin C appears to be present and essential to the normal functioning of all cellular units in higher plants and animals.[50] The following functions of the vitamin may be of importance to the Marine.

(1) It provides an intercellular cementing substance necessary for building supportive tissue, such as bone matrix, cartilage, dentine, collagen, and connective tissue.[16]

(2) It reduces ingested iron to the ferrous state, a process necessary for iron absorption.[16]

(3) It helps to mobilize stored body iron.[16]

(4) It spares several B-complex vitamins apparently by its reducing or antioxidant effect.[50]

## Additional Considerations

Continuing research is bringing to light other functions/questions of vitamin C in relation to body stressors (emotional, physical, chemical, biological, and environmental), which may be important to combat effectiveness. Stress is the nonspecific response of the body to any demand.[35] Uncertainties make it obvious that additional research is needed to determine the value of theory with ascorbic acid in stress situations. Evidence suggests vitamin C may have an effect on the following aspects of the military experience.

Wound healing. Evidence is abundant and convincing about the role vitamin C plays in wound healing and tissue repair. The "cementing action" of vitamin C makes it an important agent in wound healing. It seems ascorbic acid is mobilized from the tissues and organs and selectively concentrated in the traumatized area with a resulting decrease in plasma levels and urine output.[39] Studies indicate that the vitamin C deficiency must be quite severe before wound healing is inadequate. In one study, subjects were depleted of tissue ascorbic acid stores then given an incisional skin wound followed by daily doses of either 4, 8, 16, or 32 mg of ascorbic acid. In all cases wound healing proceeded to completion and no evidence of varying healing rates was noted.[38]

Cold climates. Some evidence indicates increasing vitamin C (250-300 mg/day) to near saturation intake in reduced environmental temperatures stimulates the processes essential to homeostasis, which may accelerate the acclimitization period.[39,54] Other studies indicate there is no change in mental or physical performance with supplementation in cold climates.

Hot climates. Studies with controlled intakes of vitamin C have not shown significant benefits (stability, psychomotor and strength) from high ascorbic acid intakes in hot climates.[39] There is, however, conflicting evidence as to whether vitamin C requirements are affected by hot climates due to possible losses through sweat.[39]

Emotional stress. Severe emotional stress apparently does increase catabolism of ascorbic acid and might warrant higher intakes of vitamin C.[38] Considerable evidence suggests that the requirement is increased by trauma, infections, and other stress situations.

Common colds. There is little convincing evidence to support claims of vitamin C protecting against the common cold.[1,51]

Chemical/Biological protection. Some evidence indicates that vitamin C may play a role in detoxication of poisonious substances by its cofactorial role.[55]

## Performance Implications

Whether large doses of vitamin C improve performance/endurance has been a controversial issue for nearly 40 years. Present findings indicate performance does not increase with massive dosages. (After 12 weeks of training with a 1000 mg vitamin C intake, subjects had no significant difference in a 12-minute walk/run test.[39,56,57]

## Conclusions

Ensure that tissue levels are at the saturation level by:

(1) providing a varied menu that guarantees the MRDA vitamin C requirement in the pre- and postoperational menu;

(2) making vitamin C available in the operational ration;

(3) continuing research in the areas of vitamin C and its relationship to combat stress factors; and

(4) providing nutritional education to Marines.

## VII. VITAMIN A

### Overview

Serious deficiencies of vitamin A are uncommon in the developed nations. However, studies indicate that borderline deficiencies are very common in the US.[1] It is these borderline deficiencies that need to be considered. This deficiency seems to be due in part to the low acceptability of the foods that naturally contain vitamin A or its provitamins. These foods include organ meats, cream, butter, and eggs, or deep green and yellow vegetables and fruits. The fruits and vegetables (provitamins) need to be converted to vitamin A in the intestine before being absorbed into the blood stream. Because vitamin A is a fat soluble vitamin and therefore stored in the body, toxicity (hypervitaminosis A) can occur from megadoses.[16]

The MRDA and the RDA for vitamin A is 1000 RE.[3,5] The requirement in the operational ration is 1000 RE and 500 RE in the restricted ration.[5]

### Physiology

Physiological changes due to a low vitamin A intake may not appear for a year of more. Studies indicate that "relatively sedentary subjects initially well supplied with vitamin A may undergo as much as 6 months of vitamin A deprivation without developing objective or subjective evidence of vitamin A deficiency."[58]

Intake levels of service age males are inadequate by 20-33% of that required and over time this deficency could manifest in impaired night blindness (longer adaptation to see in dim lights).[59,60] It has been reported that there may be a possibility of reduced hearing acuity in some individuals.[60,61] Other more serious clinical deficiencies (less than 30 mg/200 ml blood) are very unlikely in the US population as a whole.[1,62]

Among the various clinical manifestations, those of the eye and/or the skin are predominant. In the eye the first symptom may be impaired night vision, followed by xerosis (dryness of the conjunction) of the eye. There may be other reasons for these symptoms but when coupled with low blood levels of vitamin A, a deficiency usually exists. With a prolonged deficiency, dryness, wrinkling, skin discoloration, and hyperkeratosis, will occur.[61]

There is a lag factor in making up deficiencies and storage capacity has no relation to amounts recently ingested; it depends more on individual capacity and long-term history. Depletion studies indicate recovery of blood levels to be between 6 weeks and 3 or more months.[63]

Absorption of vitamin A is dependent on good quality protein and zinc intake (see zinc and protein).[40,62] Research indicates vitamin A may play an important role in stress. This is an area where further research is required.

Depletion studies reveal no significant differences from normal either during or following mild muscular work or on the ability to perform exhausting exercise of short duration.

## Performance Implications

A slower adaptation to changes in light by the eye would cause a slower reaction time in situations requiring a split second response. The loss of hearing range or acuity would have a negative impact on performance and possibly mission accomplishment.

## Conclusions

As with most nutrients, further research as to specific functions relating to the Marine's combat scenarios and stressors needs to be done. Because vitamin A is found in foods of low acceptability and deficiencies do not manifest until intake is low for a length of time, fortification of garrison meals should be considered.

Again, nutrition education emphasizing vitamin A functions and its possible contribution in a combat situation should be provided to the Marine.

## VIII. ELECTROLYTES

### Overview

Sodium. Sodium plays several roles in the functioning of the human body, including maintaining osmotic equilibrium, extracellular fluid volume, acid-base balance, transmission of nerve impulses, and carbohydrate metabolism.[64] It is found in many foods both naturally and as an additive. Salt, which is 39% sodium, is liberally used in the food industry as both a preservative and flavoring agent.

Sodium intake has been adversely linked with hypertension, though there is much controversy over its actual role (if any).[16] The RDA has set 1100-3300 mg of sodium as the estimated safe and adequate intake for adults. This amount is below that typically consumed in the average American diet, which is generally in the 2300-6900 mg range.[3] The U.S. military has found the RDA to be impractical and unattainable for their food service system. They have therefore set an upper limit of 5500 mg/day to be implemented over the next few years. For operational rations the requirement is 5000-7000 mg and 2500-3500 mg for restricted rations (excluding salt packets).[5] However, both the RDA and the MRDA recognize and accommodate for the need for extra sodium in times of excessive losses through sweat. Both NRDEC and the U.S. military recommend that when more than 3 liters/day of water is required to replace sweat losses, sodium intake be increased to compensate (2 to 7 gm salt/liter water).[3,5]

Potassium. Potassium is essential for its role in muscle relaxation, maintaining intracellular, acid-base balance, regulating osmotic pressure, and its involvement in certain enzymatic reactions, including those necessary for protein and glycogen synthesis. It is widely distributed in foods and especially good sources include meat, fluid milk, and many fruits.

The average daily adult intake for potassium is 1950-5900 mg. Since there is a possibility that a noticeable change in the sodium:potassium ratio can have a negative effect on hypertension victims, the RDA has set an estimated safe and adequate level of 1875-5625 mg/day.[3] The military follows this guideline, decreasing the intake to 950-2800 mg for its restricted rations.[5]

### Physiology

Sodium. Deficiencies of sodium tend to occur only after prolonged sweating with inadequate replacement. This usually occurs only when little or no food is consumed since most diets are high in sodium. Symptoms include headache, weakness, giddiness, lack of concentration, poor memory, and poor appetite.[64] Sodium deficiencies generally limit work capacity due to impaired cardiovascular function. Heat cramps may occur after several days of deprivation, however other symptoms can occur earlier.

Water is of prime importance in the replacement of sodium. Without sufficient water sodium cannot be absorbed and is simply passed in the urine. Also, taking salt tablets without adequate water can result in gastric distress. It is recommended in the literature that in cases where sodium cannot be adequately replaced by the diet, a sodium-water solution (of no greater than 0.2% Na) be used instead of tablets.[9]

In cold weather environments it has been found that sufficient water is very important to prevent salt accumulation in the tissues. One field test found 3-3.5 liters/day were required for a 4500 calorie ration containing 23 gm salt (9.2 gm sodium).[65]

Sodium toxicity is very rare and occurs only in instances of excessive intakes. The body does not store sodium in abundance and generally eliminates excess amounts through the urine. On the other hand, it is also difficult to deplete the body of sodium since output in the urine is lowered to compensate for decreased intakes. In cases of long-term profuse sweating, substantial losses may occur.[66]

Potassium. Potassium balance is chiefly regulated by the kidneys. Their ability to compensate for lowered potassium intake by decreasing excretion is not as efficient as for sodium.[9] Therefore, the daily output remains relatively constant.

Appreciable losses of potassium can occur with profuse sweating. The concentration of potassium is much lower than the concentration of sodium in body sweat and losses are relatively lower(0.125 gm/hr vs. 0.601 gm/hr). It has been found that the amount of potassium in sweat decreases with acclimatization.[30]

Deprivation of potassium is generally not a problem for the average healthy individual consuming a balanced diet. When a deficiency does occur symptoms include muscle weakness, nervous irritability, mental disorientation, and cardiac irregularities. If deficiencies are left unchecked they can cause severe illness and even death. Studies indicate that the 2.6 gm potassium daily requirement supported by the MRDA would be adequate to replace losses from the urine and stools. Consequently greater than 3 gm/day would be required to maintain a positive potassium balance in cases of excessive losses due to profuse sweating especially over a prolonged period. Intakes of up to 6 gm/day have been recommended in these cases.[67]

Potassium toxicity occurs only with sudden and very high intakes (18 gm/adults). Chronic ingestion of excess potassium can lead to low-level toxicity, but metabolism by the kidneys is usually effective in eliminating excess amounts.

## Additional Considerations

Sodium. Acclimatization to heat is beneficial since acclimatization causes a decrease in the amount of sodium excreted in sweat. However, in general the amount of sodium lost in sweat is compensated for by an adjustment in the amount excreted in the urine.

Potassium. Because potassium is required for glycogen resynthesis, ample amounts must be readily available for endurance activities.[17] In cases of excessive losses, intake should be increased to compensate.

Some researchers feel that potassium loading is important to keep the body in positive (potassium) balance and prevent muscle degeneration. Daily intakes between 3.5 gm to 6 gm a day for acclimatized individuals and perhaps higher for those unacclimatized (because they would have greater sweat losses) are recommended.[67,68] If sufficient potassium can not be provided in the diet, supplements would be an acceptable alternative. Medicinal supplements are unpalatable and therefore are not recommended. Supplements should be strictly monitored because too much potassium can be dangerous.

Performance Implications

Research indicates that electrolyte supplementation does not increase performance.[10] Therefore, electrolyte intake is only of a concern to the soldier in instances where inadequate food intake coupled with profuse sweating results in excessive losses. When this occurs over a period of several days, deficiency symptoms may occur if electrolytes are not replenished. These symptoms would have a negative impact on the soldiers' performance.

Conclusions

In situations of profuse sweating, the upper limit of the MRDA is recommended. Studies indicate there are no positive benefits from excessive intake as the body does not store sodium and potassium.

When food intake is drastically reduced over a period of days, supplementation in a liquid form may be required to prevent electrolyte deficiencies and related symptoms. This should be monitored by medical personnel.

Supplementation should be in a palatable hypotonic liquid solution containing glucose, sodium, chloride, and potassium. Water is essential for the proper utilization of these electrolytes.

## IX. IRON

### Overview

The human body contains approximately 75 mg of iron per kilogram of fat free body weight. About three-fourths of this iron exists as a component of either hemoglobin or myoglobin, both of which are vital in the transportation of oxygen to body tissues. A very small amount of iron is found in enzymes and the remainder is stored in the body tissues, predominantly in the liver, spleen, and bone.[62]

The RDA for an adult male is 10 mg/day, based on a 10% availability because 1 mg/day of absorbed iron is required.[3] The MRDA for men is 10-18 mg; 18 mg for operational rations and 9 mg for restricted rations.[5] This increased requirement over the RDA is to compensate for the needs of the younger members of the military (< 18 years). It is based on the RDA for this lower age group.

Dietary iron exists in two forms (heme and nonheme). These two forms and the relative amounts of each have a direct impact on the amount of iron absorbed. The majority of iron in food is in the nonheme form. All vegetable sources of iron and approximately 60% of animal sources exist in the nonheme form.[69] Nonheme iron is both resistant to absorption and is strongly influenced by diet composition. Its absorption can be enhanced by as much as 250% by the presence of ascorbic acid.[70] Meat proteins also help promote absorption of nonheme iron. Absorption can be decreased by the presence of calcium and phosphate salts, EDTA, phytates, tannic acid, fiber and phosvitin.[1] For example, the tannic acid found in tea can decrease nonheme iron absorption by as much as 50%.[70] Heme iron can only be derived from animal sources. It is highly available and is not affected by diet composition.[1]

Meat proteins have a twofold positive effect on iron stores--they provide heme iron and promote absorption of nonheme iron. Meat proteins are therefore very good sources of iron with liver and other organs meats being the best. Additional good sources include other meat, egg yolk, whole wheat, seafood, green leafy vegetables, nuts, and legumes.[1]

### Physiology

Iron deficiency (anemia) results in a decrease in the oxygen carrying capacity of blood. Since less oxygen is available to the muscles they fatigue quicker resulting in an overall reduction in work performance. Anemia may go undetected in its early stages since it is generally diagnosed by decreased iron in the blood and it is the body's iron stores which are depleted first. Thus almost one-quarter of the body's iron supply may be lost before a deficiency would normally be identified.

There are many types of anemia. The most common is that related to blood loss. Generally rest and an iron rich diet will help restore iron levels. Since absorption of iron is related to body stores, a reduction of stores (i.e., through blood loss) would promote absorption. One study showed a recovery rate of 2 weeks to 4 months for blood doners depending on their iron stores.[1]

Nutritional anemia (anemia resulting from an inadequate supply of iron in the diet) is generally rare in men. It may be more attributable to inadequate iron absorption rather than the actual amount in the diet. Generally, the body is very efficient, increasing iron absorption and decreasing its excretion when stores are depleted. Therefore, nutritional anemia develops as a long, slow process unless deprivation is extreme.

"Sports anemia" is a condition found in athletes and others who perform hard physical work. Iron deficiency in this case is attributed to a reduction of the body's blood levels as a result of increased destruction of erythrocytes (a direct result of the physical effort) or the dilution effect an increase in blood volume would have on iron.[71] An indirect effect which can also contribute to iron deficient sports anemia would be the loss of iron in sweat, which can be significant in cases of severe perspiration.[72] Again this condition can be reversed by a combination of rest and an iron-rich diet, with a 2-week time span generally being sufficient to rebuild iron stores.

Iron toxicity is also a rarity since it is only found in case of prolonged, excessive intakes. These intakes are generally from sources additional to dietary sources. Large amounts of supplemental iron can cause constipation and should therefore be avoided.

## Additional Considerations

The entire diet of an individual must be considered to ensure that adequate iron stores are maintained as illustrated by the following two points: (1) iron deficiency anemia can be a secondary complication of vitamin A deficiency;[73,74] and (2) iron absorption can apparently be enhanced by the presence of certain minerals, including calcium and copper.

## Performance Implications

Iron deficiency has an adverse effect on work capacity and is therefore a concern of the Marine. Also, maintaining body stores would be beneficial in the event of blood loss.

## Conclusions

1. Provide nutritional awareness of iron in the body.

2. Maintain body stores of iron preoperation through iron-rich diet.

3. In cases of prolonged deprivation coupled with excessive losses through sweating, supplements may be advised.

4. Provide an iron-rich postoperation diet to replenish stores.

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Note: Apparently, iron intake over and above body's storage capacity would not have any increased effect on performance or wound healing.

## X. ZINC

### Overview

Zinc is found in most body tissues and is considered essential for the normal growth and development of all living things.[75] It is a constituent of numerous enzymes, is involved in protein synthesis, nucleic acid synthesis and both carbohydrate and insulin metabolism. As a result, zinc has been found to play a necessary role in wound healing.

Both the RDA and the MRDA for zinc are 15 mg/day for adults. The requirement remains the same for operational rations but is lower (7.5 mg) for restricted rations. Like iron, only small amounts of digested zinc are absorbed. This absorption pattern, coupled with the fact that the body contains only small amounts of biologically available zinc, supports the need for a regular dietary intake of zinc. Animal sources are better providers of zinc than plants since plant sources contain compounds (i.e., phytate, fiber) antagonistic to zinc absorption. Meat, liver, eggs, milk products and shellfish are all good providers of dietary zinc.

### Physiology

Zinc has a definite impact on wound healing, yet a controversy remains as to whether supplemental zinc will accelerate healing. It has been suggested that a benefit may be derived only in cases when a deficiency exists.[40]

Individuals under temporarily stressful conditions have been found to have a reduced level of plasma zinc. The reason for this has not been clarified so it can not be determined whether or not supplementation in times of stress would be beneficial.[40]

Zinc is necessary for vitamin A mobilization from the liver to the plasma in laboratory animals. Reduced plasma levels of vitamin A can interfere with dark adaption resulting in night blindness.[40]

### Additional Considerations

Interactions between zinc and vitamins and other minerals have been investigated. Zinc is known to be a competitive inhibitor of iron, to have an antagonistic relationship with calcium, and excessive zinc can aggregate copper deficiency.[40,75] Other relationships exist but have been less clearly defined. It is therefore essential to consider all interrelationships when planning a diet to provide adequate, absorbable zinc. Generally, diets with animal proteins provide adequate zinc. Toxicity is not a common problem since zinc is noncumulative and the proportion absorbed is thought to be inversely related to the amount ingested. Also, vomiting acts as a protective mechanism to toxicity.

### Performance Implications

The role zinc plays in wound healing and vitamin A metabolism, as well as the effect of stress on zinc levels, needs to be further researched in order to make recommendations on any potential benefits zinc supplementation may have to the combat soldier.

## Conclusions

Zinc is important to the soldier for its role in wound healing and prevention of night blindness. Dietary intake is important for these reasons as well as the concept that stress has been known to cause a decrease in plasma zinc. By providing each soldier with nutritional training and a good maintenance diet (garrison) zinc deficiencies should be prevented. Providing for this, no special requirement over the MRDA for zinc would be required for the operational ration unless proof is found that supplementation with zinc can provide additional benefits.

## XI. THIAMINE

### Overview

Thiamine plays an important role in carbohydrate metabolism and is therefore an essential nutrient. The RDA for thiamine (0.5 mg thiamin/1000 calories) is based on caloric intake because of its close interrelationship with carbohydrate and energy metabolism. The MRD for an adult male is 1.6 mg/day with a requirement of 1.8 mg for operational rations (3600 cal) and 1.0 mg for restricted rations (1200-1500 cal). A consistent intake of thiamine is required since the body does not store it in large quantities and catabolizes a percentage of thiamine at a constant rate regardless of intake.

Thiamine is not widely distributed in foods and is present in low quantities. Careful diet planning is therefore essential to ensure adequate thiamine intake. Military rations require special attention since loss of thiamine is known to occur with storage. Selected ration items with known stability are fortified with thiamine to provide adequate intake after prolonged storage. Good natural food sources of thiamine include lean pork, beef, liver, whole or enriched grains and legumes. Enrichment of such items as peanut butter and dry cocoa mixes have shown the best stability for ration use.

### Physiology

Deficiency of thiamine in the U.S. is generally not a problem due to the enrichment of grains. Even during World War II noticeable vitamin deficiencies in starvation victims were rare.[76]

However, studies have shown that acute deprivation of thiamine can result in deficiency symptoms in weeks or even days. Thiamine deficiency generally affects the personality traits and motor skills of its victim with little impact on intellectual or sensory activities. Initial symptoms include mood shifts (depression, mental confusion, apathy), fatigue, and general muscle weakness.[77] The impact of potential thiamine deficiency on the soldier is evident--he would have neither the mental attitude nor the motor skills required to perform his duties. It has been found that symptoms appear sooner with increased activity and in cold climates.[77,78] Brozek stated that "Restricted intakes of these B-complex vitamins (thiamine, riboflavin, niacin) might act as limiting factors in human motor performance even at levels well above obvious clinical deficiencies."[79] Thiamine appears to be the limiting factor in such cases since its supplementation alone has shown a tendency toward a return to normal performance within 10 days.[80] Supplementation after deprivation gave positive results, however no positive effects were found with supplementation to an ordinary good diet to healthy persons.[77]

Van der Beek found diets marginally deficient in thiamine (along with riboflavin, vitamin $B_6$ and vitamin C) to cause a decline in performance capacity as measured by the statistically significant decline in aerobic capacity and anaerobic threshold.[81]

### Conclusions

Nutritional education is stressed along with adequate pre- and postoperation thiamine intake.

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# APPENDIX E.

## Weight/Volume Comparisons of Ration Components

Weight/Volume Comparisons of Ration Components

| Ration Component | Calories/ Net Wt (g) | Ration Component | Calories/ Net Vol(cc) |
|---|---|---|---|
| Peanut Butter | 6.4 | Coconut Candy Bar | 7.9 |
| Beef Patty | 5.9 | Orange Beverage Bar | 7.6 |
| Pork Patty | 5.9 | Peanut Butter | 7.1 |
| Beef Hash-A | 5.4 | Chocolate Pudding | 7.1 |
| Beef Hash-L | 5.4 | Caramels-A | 6.4 |
| Brownie | 5.4 | Chocolate Candy-M | 6.4 |
| Chocolate Candy-L | 5.3 | Chocolate Candy-L | 6.4 |
| Chocolate Cookie | 5.3 | Granola-L | 6.1 |
| Beef w/Rice | 5.2 | Chocolate Fudge Candy Bar-L | 6.0 |
| Chicken ala King-A | 5.2 | Sweet Chocolate Candy Bar | 6.0 |
| Spaghetti-L | 5.1 | Brownie | 5.8 |
| Chocolate Candy-M | 5.1 | Vanilla Fudge Candy Bar | 5.8 |
| Chicken w/Rice-A | 5.0 | Caramels-M | 5.7 |
| Chili | 5.0 | Lemon Bar | 5.6 |
| Beef Stew-L | 4.9 | Orange Bar | 5.3 |
| Spaghetti-A | 4.9 | Chocolate Fudge Candy Bar-A | 5.2 |
| Chicken w/Rice-L | 4.9 | Oatmeal Bar | 5.1 |
| Potato Patty | 4.8 | Pepperoni | 5.0 |
| Pepperoni | 4.7 | Chocolate Cookie | 4.9 |
| Escalloped Potatoes w/Pork-A | 4.7 | Granola-A | 4.6 |
| Escalloped Potatoes w/Pork-L | 4.7 | Chocolate Nut Cake | 4.6 |
| Sweet Chocolate Candy Bar | 4.7 | Maple Nut Cake | 4.5 |
| Oatmeal Bar | 4.6 | Pineapple Nut Cake | 4.5 |
| Chocolate Nut Cake | 4.6 | Orange Nut Cake | 4.3 |
| Granola-A | 4.6 | Beef Patty | 4.3 |
| Orange Bar | 4.6 | Cherry Nut Cake | 4.2 |
| Lemon Bar | 4.6 | Cheese Spread | 4.1 |
| Beef Stew-A | 4.6 | Beef Hash-A | 4.0 |
| Maple Nut Cake | 4.6 | Vanilla Pudding | 4.0 |
| Cocoa-M | 4.6 | Fruitcake | 3.9 |
| Granola-L | 4.6 | Chicken ala King-A | 3.9 |
| Vanilla Pudding | 4.5 | Fig Bar | 3.9 |
| Chocolate Pudding | 4.5 | Pork Patty | 3.8 |
| Vanilla Fudge Candy Bar | 4.5 | Chicken w/Rice-A | 3.7 |
| Chocolate Fudge Candy Bar-L | 4.5 | Beef Hash-L | 3.6 |
| Coconut Candy Bar | 4.5 | Spaghetti-A | 3.6 |
| Chicken Stew-A | 4.4 | Apple Jelly | 3.6 |
| Crackers | 4.4 | Beef Jerky | 3.5 |
| Chicken Stew-L | 4.3 | Sugar | 3.5 |
| Caramels-M | 4.3 | Chewing Gum | 3.5 |
| Pineapple Nut Cake | 4.3 | Beef Stew-L | 3.4 |
| Orange Nut Cake | 4.2 | Escalloped Potatoes w/Pork/A | 3.4 |
| Cherry Nut Cake | 4.1 | Beef Stew-A | 3.4 |
| Cheese Spread | 4.0 | Chili | 3.3 |
| Caramels-A | 4.0 | Chicken Stew-A | 3.3 |

A=AP L=LRP M=MRE

Weight/Volume Comparisons of Ration Components (cont'd)

| Ration Component | Calories/ Net Wt (g) | Ration Component | Calories/ Net Vol(cc) |
|---|---|---|---|
| Fruitcake | 4.0 | Apple Jelly | 3.1 |
| Cream Substitute | 4.0 | Escalloped Potatoes w/Pork-L | 3.1 |
| Sugar | 4.0 | Spaghetti-L | 2.9 |
| Orange Beverage Bar | 4.0 | Hot Dog | 2.9 |
| Mixed Fruit | 3.9 | Catsup | 2.7 |
| Chocolate Fudge Candy Bar-A | 3.9 | Cocoa-M | 2.7 |
| Strawberries | 3.9 | Beef w/Rice | 2.5 |
| Peaches | 3.9 | Cream Substitute | 2.3 |
| Fig Bar | 3.6 | Potato Patty | 2.1 |
| Beef Jerky | 3.3 | Crackers | 2.1 |
| Catsup | 3.3 | Chicken w/Rice-L | 2.1 |
| Coffee | 3.0 | Meatballs | 2.0 |
| Chewing Gum | 2.9 | Beef, Ground | 1.9 |
| Hot Dog | 2.7 | Beef Slices | 1.8 |
| Apple Jelly | 2.7 | Chicken Stew-L | 1.8 |
| Apple Jelly | 2.7 | Soup & Gravy Base Beef | 1.7 |
| Soup & Gravy Base, Beef | 2.1 | Ham Slices | 1.7 |
| Meatballs | 1.7 | Beans w/Tomato Sauce | 1.5 |
| Beef, Ground | 1.7 | Ham & Chicken Loaf | 1.5 |
| Beef Slices | 1.6 | Beef Stew-M | 1.4 |
| Ham Slices | 1.5 | Diced Beef | 1.4 |
| Beans w/Tomato Sauce | 1.4 | Diced Turkey | 1.4 |
| Ham & Chicken Loaf | 1.3 | Chicken ala King-M | 1.3 |
| Beef Stew-M | 1.3 | Coffee | 1.2 |
| Diced Beef | 1.2 | Mixed Fruit | 0.9 |
| Diced Turkey | 1.2 | Applesauce | 0.8 |
| Chicken ala King-M | 1.2 | Strawberries | 0.6 |
| Applesauce | 0.7 | Peaches | 0.5 |

A=AP L=LRP M=MRE